



Jefferson Lab Radiation Control Manual

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REFERENCES:

The following reference documents are used for guidance regarding this chapter. The CFR web site <http://www.gpoaccess.gov/cfr/index.html> contains further information on this reference material.

10 CFR 820

10 CFR 835



PART 1 Jefferson Lab Radiological Control Manual

100 Radiation Control Group Mission Statement

The Radiation Control Group will support the Laboratory Mission by helping achieve the scientific and technical goals and by helping to protect laboratory workers and the surrounding public and environment from unnecessary ionizing radiation exposure due to Jefferson Lab operations.

110 Mission Implementation Strategy

Jefferson Lab, operated for the Department of Energy by Southeastern Universities Research Association, Inc. (SURA), is committed to having a high quality Radiological Control Program. The program will be conducted using sound industry practice in a cost-effective manner. The Standard of Care will be the applicable regulations (e.g., 10 CFR 835), but As Low As Reasonably Achievable (ALARA) will be the guiding principle. The program will rely on training, workplace monitoring, radiation work controls, radioactive materials control, and environmental monitoring. Radiation control professional and technical staff, assisted in certain routine activities by other specially trained lab staff members, will implement the program. The radiation control professional and technical staff will make recommendations to line management on radiation safety, conduct radiation surveys, directly monitor personnel and radiation related work activities, evaluate the effectiveness of controls and processes, and ensure that the program is conducted in accordance with all applicable legal requirements.

111 Radiological Control Policy

Jefferson Lab makes the following policy statements in support of its radiological controls program and applicable legal requirements.

1. SURA/Jefferson Lab management is responsible for compliance with the requirements of 10 CFR 835 and implementation of related programs, plans and schedules.
2. No employee or contractor of SURA/Jefferson Lab, or any DOE employee shall take or cause to be taken any action inconsistent with the requirements of 10 CFR 835 or any related program, plan, schedule, or other process established or required by 10 CFR 835.
3. Nothing in this RadCon Manual or any part of 10 CFR 835 shall be construed as limiting actions that may be necessary to protect health and safety.
4. Radiation dose will not exceed the following statutory limits:
 - a) Radiation workers shall not receive a dose of more than 5 rem per calendar year total effective dose equivalent.
 - b) Non-radiation workers shall not receive a dose of more than 0.1 rem per calendar year total effective dose equivalent.



5. Exposure to ionizing radiation should be kept ALARA, taking into account the net benefit obtained as a result of the exposure. There should not be any occupational radiation exposure of workers to ionizing radiation without the expectation of an overall benefit from the activity causing the exposure. This policy is applied to personnel and environmental radiation protection.
6. Jefferson Lab has established action levels and design goals consistent with ALARA. Action levels are below the statutory limits given above. If the action level is exceeded, a local investigation shall be made to ensure that ALARA is being observed. Design goals were utilized in the design of Jefferson Lab and are used in any subsequent modification or new construction. They are lower than action levels and are intended to provide assurance that ALARA is included in the basic design and operation. Design goals include considerations for:
 - a) maintaining individual worker dose less than 250 mrem per year
 - b) preventing degradation of groundwater quality
 - c) controlling of contamination by engineered means where possible
 - d) minimizing the generation of radioactive material.
7. The Jefferson Lab Radiation Review Panel (JRRP) serves as an ALARA Committee. The membership includes managers and workers from the scientific and technical Divisions and Departments and the Radiation Control Group. The Jefferson Lab Radiation Review Panel Charter is found in the Jefferson Lab Environmental Health and Safety (EH&S) Manual (Chapter **2240 Jefferson Lab EH&S Committees**). The JRRP makes recommendations to management to improve processes in minimizing radiation exposure and preventing radiological releases. This committee may evaluate items such as construction, design, and modification of laboratory facilities and systems and planned major modifications or work activities.

112 Manual use for Statutory Compliance and Sound Industry Practice

This manual establishes the requirements of Jefferson Lab's Radiation Protection Program (RPP) based on 10 CFR 835 and ensures that Radiation Control activities are conducted in accord with this RPP. The content of this manual is commensurate with the nature of the activities performed and includes formal plans and measures for applying the ALARA process to occupational exposure and for implementing the requirements of 10 CFR 835.

The word "shall" identifies those elements considered to be mandatory due to statutory requirements or laboratory policy and practice. The Radiation Control Manager, as defined in [Article 141](#), may temporarily authorize exceptions to laboratory policy if an acceptable alternative approach is obtained. Exceptions to statutory requirements can be obtained only after approval by the regulatory agency.

The word "should" means that the provision is a proven practice that supports compliance with the basic requirements found in applicable regulations or DOE Orders or their underlying basis documents for occupational radiation protection. The use of "should" recognizes that: 1) there may be site- or facility-specific attributes that warrant special treatment; 2) the safety benefit derived from implementation of the provision may not in all cases be commensurate with the



associated detriments (e.g., financial cost, worker discomfort, schedule conflicts, etc.); and 3) literal compliance with the provision may not achieve the desired level of radiological performance.

The manual is also intended to be consistent with other relevant statutory and regulatory requirements, and is revised whenever necessary to help maintain consistency. The content of the RPP shall address, but shall not necessarily be limited to, each requirement in 10 CFR 835. The manual incorporates other requirements and recommendations based on generally accepted sound industry practices for the conduct of radiological controls. The provisions in the manual should be viewed by Jefferson Lab personnel as an acceptable technique, method or solution for fulfilling their duties and responsibilities. This manual is applicable to the conduct of all radiological operations at Jefferson Lab including subcontracted operations on-site. DOE employees at Jefferson Lab are subject to and shall adhere to the provisions of this manual.

113 Changes to the Radiation Protection Program Plan and the RadCon Manual (a supplement of the EH&S Manual)

Changes in the RadCon Manual may occur from time to time. Jefferson Lab promotes active communication with similar research laboratories and attempts to ensure that “lessons learned” are incorporated into the RadCon Manual and into routine practice. Recommendations for change related to statutory requirements shall be submitted to the Laboratory Director for concurrence before incorporation into the RadCon Manual. Changes in statutory requirements shall not be implemented until an update of the Jefferson Lab RPP and related parts of the RadCon Manual are approved by DOE as required by 10 CFR 835. The DOE may direct or make modifications of an RPP. A change or addition of a task not within the scope to the RPP will be submitted to the DOE within 180 days of the effective date of the change. Approval of the change by DOE is required prior to the initiation of the tasks or actions related to the change. DOE approval for changes to the RPP is not required if the changes do not decrease the effectiveness of the RPP or the changes to the RPP do not affect Jefferson Lab’s compliance status with 10 CFR 835. An initial RPP or an update shall be considered approved 180 days after its submission unless rejected by DOE at an earlier date.

The RadCon Manual is a controlled document and shall be kept current. Note that the RPP is a separate entity from the RadCon Manual. Various sections of the RadCon Manual serve as evidence of implementation of the RPP.

PART 2 Radiological Controls and Responsibilities in the Laboratory Organization

A successful radiological controls program can be achieved when qualified personnel use approved procedures and management actively monitors the workplace and assesses ongoing activities. Regular review and informed interest by line management is necessary to ensure a successful Radiological Control Program. Management leads by example. Management at all levels should emphasize by involvement the need for high standards for radiological control through planning, instructions and communication, and regular inspection of the workspace. Key principles for ensuring a well-managed Radiological Control Program are provided in this Chapter. Managers at all levels are expected to be involved in the planning, scheduling and conduct of radiological work. Assurance of adequate radiological safety should not be compromised to achieve research objectives. Rather, a successful research program promotes radiological safety and supports the ALARA process.

121 Laboratory Senior Management Roles and Responsibilities

1. The Laboratory Director approves overall goals for radiation protection at the Lab and monitors the overall radiological performance by external peer reviews, self and independent assessments, and by written or verbal communication with the Radiological Control Manager (RCM). The Director shall ensure that the application of statutory and laboratory practice in radiological controls is not impeded by conflicts of interest and should concur in any job performance rating given to the RCM.
2. The Accelerator Division Manager/Associate Director shall ensure that adequate resources are available to meet all laboratory-wide statutory radiological control requirements, such as Radiation Worker Training and environmental permits. The Accelerator Division Manager/Associate Director should establish realistic, challenging, measurable goals and objectives for the performance of radiological controls. Performance on these goals should be reviewed at least annually. Each Division Manager/Associate Director shall ensure that sufficient resources are allocated, including personnel, and workers are properly trained and qualified for radiological controls associated with their assigned duties.
3. The Accelerator Division Environment, Health, and Safety (EH&S) Department Head is responsible for immediate oversight of Radiation Control Group activities. This manager should ensure that adequate resources and authority exist to specify radiation controls and to monitor work throughout the Laboratory.
4. The Accelerator Division EH&S Department Head should ensure that opportunities for minimizing the generation of radiological waste and discharges to the environment, controlling contamination at its source, and reducing radiation exposure to workers and the public are incorporated into laboratory work practices.



5. Ensuring that laboratory staff has received appropriate radiological control training is the responsibility of line managers and their subordinates. Training, in most cases, will be provided by the Radiation Control Group training organization, but the responsibility for effective translation to work practice rests with line management.
6. Managers and first-line supervisors should be sensitive to the fact that workers perform radiological duties and ensure that the workers understand the fundamentals of radiation, its risks, and their role in minimizing exposure. It is not sufficient to rely solely on regulatory limits for establishing or defining acceptable work practices and work environments. Managers should refer individuals who are concerned about radiation exposure to Occupational Health & Safety or to the Radiological Control Manager.
7. Line managers should solicit feedback from radiological control professionals, line supervisors and workers on radiological control performance, and should hold workers and their supervisors accountable for radiological control performance. Relevant knowledge and performance should be assessed as a specific part of each person's performance evaluation.
8. Supervisors should be involved in the scheduling and conduct of radiological work, and also ensure that workers understand the controls associated with the radiological work that they are to perform.
9. Line managers should periodically monitor work areas to observe personnel at work and to identify radiological deficiencies and concerns.
10. Supervisors and managers should encourage the work force to identify radiological control deficiencies and concerns. Prompt action should be taken to address and eliminate identified issues and prevent recurrence.
11. Managers and supervisors should establish working conditions that encourage improved radiological control. Work conditions such as temperature, humidity, lighting, and accessibility should be considered in planning work. Cleanliness and good housekeeping are essential to a good Radiological Control Program.
12. Subcontractors, subcontracted employees and Physics users (or other members of the scientific community utilizing Jefferson Lab facilities) should be treated the same as facility staff in the area of radiological matters, should have comparable training, and shall meet the same requirements and expectations.

122 Laboratory Worker Roles and Responsibilities

Minimizing worker radiation exposure requires that all persons involved in radiological activities have an understanding of radiation hazards and mitigating measures.

1. Each worker should understand the radiation control aspects of their daily duties and integrate proper radiological controls into those duties.

2. Cooperation between the work force and the Radiation Control Group has to be developed and fostered. Workers should not look upon radiological controls as hurdles or restrictions to be bypassed. Concerns regarding radiological controls that appear to be overly restrictive or too lax should be immediately brought to the attention of line management for review by the Radiation Control Group.

A situation in which radiological controls are left solely to the Radiation Control Group is unacceptable. Line managers are ultimately responsible for ensuring that radiological controls are properly implemented and radiation exposures are maintained ALARA. Radiation Control Group (RCG) personnel should be helpful in showing workers how to keep their exposure ALARA. This spirit of cooperation, however, should be developed without subverting the control functions of the Radiological Control Technologists.

123 Enhanced Worker Training and Increased Awareness of Radiological Conditions

In performing assigned duties within radiological areas, workers should be familiar with the area radiological conditions and be aware of the possibility that changes may occur due to unforeseen reasons. Although the conduct of radiological surveys is viewed as a traditional role of Radiological Control Technologists, experience has shown that properly trained and qualified workers are capable of performing supplemental radiological surveys in the course of work. Jefferson Lab employs the use of specially trained staff members called Assigned Radiation Monitors to provide supplemental radiological control support. Assigned Radiation Monitor duties include accelerator enclosure, end station, and FEL entry surveys and review of general conditions for conformance to radiological control requirements.

The performance of surveys of complex, first time activities and where a broader knowledge of survey techniques or legal requirements is necessary, such as release surveys, remains the responsibility of qualified Radiological Control Technologists.

124 Marginal Radiological Control Performance

1. When radiological control performance is less than adequate, consideration should be given to strengthening line management oversight and increased oversight by the Radiation Control Group to ensure adequate radiological control. A Radiation Safety Deviation Report (RSDR) per [Article 126](#) should be used to document deficiencies and implement a structured plan for improvement.
2. In cases where the work force does not have the required level of sensitivity for radiological work practices, additional management attention is needed to assure the proper outcome. Line management will be held accountable for implementation of the Radiological Control Program. Initial remedial actions may include:
 - a. More direct line supervision in the workspace
 - b. Curtailment of work schedules
 - c. Deferral of work
 - d. Additional radiological control personnel assigned to monitor work
 - e. Conduct additional training.



3. When the workers and supervisors achieve the proper level of radiological performance, the number of radiological control personnel and additional control measures should be evaluated and revised to reflect performance.

125 Critiques

It is Jefferson Lab Management's desire and expectation, based on concern for the safety and well-being of workers and the general public, that radiological work practices be reviewed so that opportunities for improvement can be incorporated into work practices.

Formal processes are established to obtain pertinent facts following a report of unsafe practices, unusual radiological situations, or at the satisfactory conclusion of a new or unusual operation involving radiological controls. These processes complement the Jefferson Lab Occurrence Reporting and Processing System (ORPS) of EH&S Manual Chapter **5300 Occurrence Reporting** established by contract. These processes can be used to quickly establish facts so that the underlying reasons or causes for the success or failure are well understood. Work force participation is encouraged. Critiques are a management tool and should not be used to "fix blame" or to "shoot the messenger."

Note that the Notable Event reporting process of EH&S Manual *Appendix 5300-T3 Notable Event and Notification Procedure* should be used to document anomalous radiological conditions (such as unusual or inexplicable radioanalytical results not exceeding a regulatory limit); whereas violations of regulations, procedures or policy subsequently leading to a reduction in radiation safety should be reported through the Radiation Safety Deviation Report process of Article 126. The Notable Event reporting process can also be used for isolated minor radiological concerns that do not have the potential for a significant reduction in radiation safety.

The Jefferson Lab Environmental Health and Safety Committee has established a subcommittee called the Jefferson Lab Radiation Review Panel (JRRP). It functions as the organization for critiques dealing with internal radiological control matters. The responsibilities and guidelines for the JRRP are incorporated into the Jefferson Lab *EH&S Manual*.

A formal review process, such as the Accelerator Readiness Review Process or the Experiment Equipment Review Process, will serve to review radiation controls at the beginning of a new or unusual phase of operations or at the satisfactory conclusion of a new or unusual operation involving radiological controls.

126 Radiation Safety Deviation Reports

1. A Radiation Safety Deviation Report (RSDR) is a means to identify, document, report and initiate a path for improvement for marginal or unsatisfactory radiological work performance and adverse or anomalous radiological conditions.
2. An RSDR should be initiated for any of the following situations.
 - a. Violations of radiation rules or policy from the Jefferson Lab *EH&S Manual* or this supplement
 - b. Violations of RWP conditions
 - c. Performance of test plans with the potential for steering accelerator beam off a high power beam dump face without prior RCM approval



- d. Installation, modification or removal of personnel protection shielding without RCG concurrence
 - e. Loss of tracked radioactive sealed sources or radioactive material
 - f. Installation of He-3 bottles with H-3 (tritium) content exceeding 10 mCi in an experimental hall without written RCM approval
 - g. Exceeding administrative dose limits for an individual
 - h. Exceeding limits on radiological conditions of environmental permits held by Jefferson Lab (e.g., Hampton Roads Sanitation District (HRSD) tritium discharge limits, Virginia Pollutant Discharge Elimination System (VPDES) tritium groundwater limits)
 - i. Anomalous radiological trends (e.g., an inexplicable increase of tritium at a level below the permit limit at a groundwater monitoring well)
 - j. Any radiological condition that can lead to a detrimental effect to Jefferson Lab as determined by the RCM
3. The RSDR can be initiated by anyone, but should involve at least one member of the RCG. When a radiological condition warranting an RSDR is identified, the RCG should be notified, and a critique per [Article 125](#) should be held. The condition and possible root causes should be identified. Actions taken to remedy the condition should be assigned to personnel capable of implementing the corrections. The RCG member should fill out the RSDR online on the Accelerator Tracking, Trending and Training page. Corrective actions should be assigned, and it is the responsibility of the RCG member to ensure that responsible parties are informed of their respective duties. Note that members of the Physics Division need to be informed through the Physics EH&S Officer.
 4. A copy of the RSDR shall be forwarded to the Jefferson Lab Price Anderson Amendments Act (PAAA) Coordinator (EH&S Reporting Manager) in order to determine if it meets any of the reporting requirements of [Appendix 5300-T4 Worker Radiation Protection Rulemaking \(10 CFR 835\) Reporting](#).
 5. A separate RSDR and accompanying critique should be initiated in the event that an additional radiological deficiency or concern is identified while completing corrective actions assigned in the original RSDR.

PART 3 Improving Radiological Performance

131 Radiological Performance Goals

Goals are intended as a measure of, and a motivation for, improvement, not as an end in themselves.

These performance indicators are not to be viewed narrowly as numerical goals. These indicators are used as tools to assist management in focusing their priorities and attention. The following are some examples of the goals that may be appropriate:

1. A reduction of collective dose (person-rem) based on planned activities and historical performance.
2. Minimal personnel contamination or intakes of radioactivity.
3. A reduction in the number of contaminated surfaces.
4. Minimization of the generation of liquid or solid radioactive waste.
5. Minimizing the unnecessary storage of activated material.

Other goals may be selected as the scope or conduct of operations changes.

132 Metrics and Management of Radiological Performance Goals

1. The Associate Director of the Accelerator Division should establish, approve and review radiological performance goals. These may be the same as, but not necessarily limited to, those used for contract performance metrics.
2. The performance goals should be measurable, achievable, and auditable.
3. Radiological performance goals should be reviewed periodically and revised as appropriate.

133 Radiological Performance Reports

1. The Radiation Control Manager should provide a periodic summary report to the Laboratory Director. This report should be made at least annually and should include any pertinent information related to radiological performance goals.
2. The Radiation Control Manager should provide appropriate feedback to supervisors and managers on a basis frequent enough to permit management of any associated exposure control. The frequency should be consistent with the nature of the workload and the radiation exposure potential.
3. To promote worker awareness of their radiation exposure status, selected indicators related to their work group may be incorporated into technical work documents.



134 Internal Audits

1. Internal audits shall address the nine functional elements of the radiation protection program no less frequently than every 36 months. These elements follow:
 - a. operational health physics practices,
 - b. portable and fixed instrumentation,
 - c. ALARA (within the context of work planning, dose minimization, and environmental monitoring),
 - d. source control,
 - e. radiation surveys, posting and classification of areas,
 - f. dosimetry,
 - g. environmental monitoring,
 - h. training, and
 - i. record keeping.
2. An audit should be conducted in accordance with an approved audit plan. The Radiation Control Group may generate a preliminary audit plan for use by the auditor.
3. The Accelerator Division EH&S Department Head and the Radiation Control Manager should approve the audit plan.
4. The Accelerator Division EH&S Department Head should be made aware of any immediate hazards on the day of any audit and should review the results of the audit within one week. The Accelerator EH&S Department Head should receive a copy of all audit results. The subject of the audit (group or individual) should prepare a written response within one week addressing the findings of the audit. The JRRP Chair should be provided the results of internal audits at the next scheduled meeting.
5. The internal audits referred to in this section do not preclude, and may be mutually substituted for, other audits (by Jefferson Lab organizations) covering the same operational areas in order to separately satisfy their own organizational requirements.
6. The internal audit may be conducted by the Radiation Control Group or other oversight organizations as appropriate. Jefferson Lab may invite experts to participate in or conduct internal audits.



PART 4 Radiation Control Group

141 Radiation Control Group

1. The Radiation Control Manager (RCM) heads the Radiation Control Group and is responsible for administering the Jefferson Lab Radiological Control Program. The RCM reports to the Accelerator Division EH&S Head in the line organization. The RCM shall have direct access to the Division Associate Directors and to the Laboratory Director to ensure all radiological controls associated with laboratory operations are properly implemented.
2. Radiological control staff are tasked with monitoring adherence to the Jefferson Lab Radiological Control Manual and are available to the facility line management for radiological support to the work force. To ensure independence in making correct radiological decisions, the Radiation Control Group is directly accountable to the RCM.

142 Radiation Control Group Functions and Staffing

1. The RCM shall be an experienced professional in radiological control and shall be familiar with the design features and operations of the facility that affect the potential for exposures of persons to radiation. Qualifications for the position should include a bachelor's degree in science or engineering, at least five years of professional experience, and certification by the American Board of Health Physics.
2. The senior staff of the Radiation Control Group includes health physicists and may include professionals with degrees in physics, science, or engineering. Pursuit of certification by the American Board of Health Physics for senior and professional staff members is encouraged.
3. Radiological Control Technologists (RCTs) are support personnel who provide health physics and radiological engineering, dosimetry, independent oversight, instrumentation and calibration functions. Radiological Control Technologists provide work planning and assist in the implementation of radiological control, perform radiological analyses, and support the environmental monitoring program. Radiological Control Technologists have the responsibility and authority to stop work or mitigate the effect of an activity if they suspect that continued performance of a job or evolution or test will result in the violation of radiological control standards, result in imminent danger or unacceptable risk, or result in the inadvertent release of radioactive material to the environment. Any Laboratory staff member has stop work authority in accordance with the Lab *EH&S Manual*. Pursuit of registry by The National Registry of Radiation Protection Technologists is encouraged.

143 Relationship Between Radiological Control Technologists and Workers

Radiological Control Technologists (RCTs) and their supervisors perform the functions of assisting and guiding workers in the radiological aspects of the job.

1. Radiological workers are sufficiently qualified to recognize the symptoms of deteriorating radiological conditions and to seek advice from their supervisors and from Radiological Control Technologists.
2. Radiological Control Technologists and their supervisors have the responsibility and authority to stop radiological work or mitigate the effect of an activity if they suspect that the initiation or continued performance of a job, evolution or test will result in the violation of radiological control standards or result in imminent danger or unacceptable risk. Through their supervisor, any worker also has stop work authority in accordance with [Article 345](#).
3. The actions or presence of radiological control personnel does not absolve the workers of their responsibility for properly conducting radiological aspects of the job. Radiological control personnel are not present to compensate for poor management of the work force and should not be required to do so. A poorly trained work force should participate in an accelerated training program.

144 Quantities and Units Used in Radiation Control

Unless otherwise specified, the quantities used in the records in the Radiation Control Program at Jefferson Lab are the special units of curie, rad, or rem, including multiples and subdivisions of these units. The Standard International (SI) units becquerel (Bq), gray (Gy), and sievert (Sv) may be provided parenthetically for reference with scientific standards. SI units should not be used in records required for the Radiation Control Program at Jefferson Lab.

For those activities that are required by Articles [134](#), [613](#), [642](#), [451](#), and [452](#), the time interval to conduct these activities may be extended by a period not to exceed 30 days to accommodate scheduling needs.



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REFERENCES

The following reference documents are used for guidance regarding this chapter. The CFR web site <http://www.gpoaccess.gov/cfr/index.html> contains further information on this reference material.

Jefferson Lab *EH&S Manual*
NCRP 26
NCRP 30



PART 1 Administrative Control Level and Dose Limits

Exposure to ionizing radiation, however small the amount, is presumed to involve some risk. To this end, limits for the amount of ionizing radiation dose, structural design considerations, and good work practices, have been adopted as methods of exposure control at Jefferson Lab. Although all facilities have been designed and constructed to minimize exposure, and limits and good work practices are enforced, final responsibility for personnel exposure control rests with the individual worker.

211 Administrative Control Level

The following administrative limits have been established at Jefferson Lab for exposure to ionizing radiation:

1. A DOE Administrative Control Level of 2,000 mrem per year per radiological worker (whole body) is established for all DOE activities. Approval by the Program Secretarial Official or designee shall be required prior to allowing a person to exceed 2,000 mrem.
2. The dose above which a local investigation shall be initiated (Jefferson Lab Action Level) is 1000 mrem per calendar year. No person shall be allowed to go above the Action Level without the prior approval of the Jefferson Lab Director.
3. To maintain positive control of radiological worker exposure, an exposure alert system is in effect at Jefferson Lab. When a radiological worker's annual radiation dose approaches or exceeds 250 mrem (Jefferson Lab Alert Level), the worker and his/her supervisor shall be notified that his/her exposure is at or has exceeded the Jefferson Lab design goal. The worker should then consult with his/her supervisor and with the RCG to ensure that supervisor and worker are doing as much as possible to minimize exposure to radiation and adhere to the ALARA program.
4. The Alert level for members of the public and general employees who are not radiological workers is 10 mrem. This dose may be either determined by estimation or measurement. See [Table 2-1A](#). Exposures shall be kept below the limits in this table and maintained as low as reasonably achievable.

Table 2-1A Annual Dose Equivalent Limits & Levels

	Occupational	General Public (total) ^a
Annual Limit	5000 mrem (50 mSv)	100 mrem (1 mSv)
Action Level	1000 mrem (10 mSv)	50 mrem (0.50 mSv)
Jefferson Lab Design Goals (Alert Level)	250 mrem (2.5 mSv)	10 mrem (0.1 mSv)

a. There are additional restrictions that apply to specific pathways of exposure. See Chapters 6310 and 6311 of the Jefferson Lab EH&S Manual.

Table 2-1B Annual Organ/Extremity Dose Equivalent Limits & Levels

Type of Exposure	Annual Limit	Action Level	Alert Level
Lens of Eye	15 rem	3 rem	1 rem
Extremity (hands and arms below the elbows; feet and legs below the knees) and skin of whole body)	50 rem	10 rem	2.5 rem
Any organ or tissue (other than lens of eye, but including skin of whole body) See Appendix 2C and footnote below ^{ab}	50 rem	10 rem	2.5 rem

- a. 1. If the area of skin irradiated is 100 cm² or more. The non-uniform dose equivalent received during the year shall be averaged over the 100 cm² of the skin receiving the maximum dose, added to any uniform dose equivalent also received by the skin, and recorded as the shallow dose equivalent to any extremity or skin for the year.
2. If the area of skin irradiated is 10 cm² or more, but is less than 100 cm². The non-uniform dose equivalent (H) to the irradiated area received during the year shall be added to any uniform dose equivalent also received by the skin and recorded as the shallow dose equivalent to any extremity or skin for the year. H is the dose equivalent averaged over the 1 cm² of skin receiving the maximum absorbed dose, D, reduced by the fraction f, which is the irradiated area in cm² divided by 100 cm² (i.e., H=fD). In no case shall a value of f less than 0.1 be used.
3. If the area of skin irradiated is less than 10 cm². The non-uniform dose equivalent shall be averaged over the 1 cm² of skin receiving the maximum dose. This dose equivalent shall be recorded in the individual's occupational exposure history as special entry; and will not be added to any other shallow dose equivalent to any extremity or skin recorded as the dose equivalent for the year.
- b. For the purpose of monitoring individual exposures to internal radiation, internal dose evaluation programs (including routine bioassay programs) shall be conducted for radiological workers who, under typical conditions, are likely to receive 0.1 rem (0.001 sievert) or more committed effective dose equivalent, and/or 5 rem (0.05 sievert) or more committed dose equivalent to any organ or tissue, from all occupational radionuclide intakes in a year.
 1. The total effective dose equivalent during a year is determined by summing the effective dose equivalent from external exposures and the committed effective dose equivalent from any occupational intake of radionuclides during the year.
 2. Deep dose equivalent to the whole body may be used as effective dose equivalent in evaluating external exposures. Determinations of the effective dose equivalent will be made using the weighting factor values provided in Appendix 2B.
 3. For the case of uniform external irradiation of the whole body, a weighting factor equal to 1 may be used in determination of the effective dose equivalent.
 4. Any method used for internal and external monitoring shall be adequate to demonstrate compliance with limits for radiological workers, declared pregnant radiological workers, minors, and members of the general public.

212 Radiological Worker Dose Limits

Routine Occupational Exposure

A radiological worker is any individual whose whole body may, in the course of his/her occupational duties at Jefferson Lab, be exposed to radiation that could produce a dose above 100 mrem per year. The following limits have been established at Jefferson Lab for occupational exposure to ionizing radiation:

1. The annual exposure limits for radiological workers is found in the Occupational and Annual Limit columns of Tables [2-1A](#) and [2-1B](#). Occupational exposure to Jefferson Lab radiological workers resulting from DOE activities, other than planned special exposures and emergency exposure situations indicated below, shall be controlled so the annual limits listed in Tables [2-1A](#) and [2-1B](#) are not exceeded.



2. All occupational exposure received during the current year is applied to these limits. Doses from background, therapeutic and diagnostic medical radiation, and voluntary participation in medical research programs shall not be included in dose records or in the assessment of compliance with the occupational exposure limits.
3. Radiological workers from other DOE or DOE contractor facilities may receive occupational exposure as a radiological worker if they:
 - a. Provide record of current Radiological Worker I or II standardized core training
 - b. Receive site-specific Radiological Worker I or II training at the facilities where they will be working and
 - c. Provide for transfer of their radiation dose records for previous years and written estimates for the current year.

Radiological workers are required to stay within Special Control Levels until verification of previous dose is received by the Radiation Control Group (see [Article 217](#)).

Accidents and Emergencies

4. A general employee whose occupational exposure has exceeded the numerical value of any of the limits specified in Occupational and Annual Limit columns of Tables [2-1A](#) and [2-1B](#) (as a result of an authorized emergency exposure) may be permitted to return to work in radiological areas during the current year providing that all of the following conditions are met:
 - a. Approval is first obtained from the contractor management and the Head of the responsible DOE field organization,
 - b. The individual receives counseling from radiological protection and medical personnel regarding the consequences of receiving additional occupational exposure during the year,
 - c. The dose has been recorded in the individual's occupational dose record, and
 - d. The affected employee agrees to return to radiological work.

The table in [Appendix 2A](#) contains Guidelines for Control of Emergency Exposures.

5. When the conditions under which the emergency or accidental exposures were received have been eliminated, Jefferson Lab management will notify appropriate DOE Authority as indicated in the DOE approved Jefferson Lab Occurrence Reporting and Processing System in Chapter **5300 Occurrence Reporting** of the *EH&S Manual*.
6. Operations at Jefferson Lab that use or produce ionizing radiation or radioactive material, which have been terminated after an emergency or accidental exposure in excess of the limits specified in [Table 2-1A](#), will be resumed only with the approval of the DOE Site Office Manager or designee.
7. Jefferson Lab does not anticipate rescue or recovery actions resulting in exposure in excess of applicable regulations. However, Jefferson Lab will minimize the risk of injury to those individuals involved in rescue and recovery operations. Jefferson Lab management will weigh actual and potential risks to rescue and recover individuals against the benefits to be gained. Volunteers will perform any rescue actions at Jefferson Lab that might involve substantial personal risk. Each Jefferson Lab employee selected should be trained in accordance with [Article 632](#) and briefed beforehand of the known or anticipated hazards to which the individual will be subjected.

213 Planned Special Exposures for Radiological Workers

1. A planned special exposure may be authorized for a radiological worker to receive doses in addition to and accounted for separately from the doses received under the limits specified in RCM Tables [2-1A](#) and [2-1B](#) provided that the following conditions are satisfied:
 - The planned special exposure is considered only in an exceptional situation when alternatives that might prevent a radiological worker from exceeding the limit in Table [2-1A](#) are unavailable or impractical.
 - The proposed activity is reviewed by the Jefferson Lab RCM and Director and is submitted in writing for approval by the DOE.
 - Joint written approval from the appropriate DOE Headquarters program office and the Assistant Secretary for Environment, Safety and Health or equivalent is received.
2. Prior to requesting an individual to participate in an authorized planned special exposure, the individual's dose from all previous planned special exposures and all doses in excess of occupational dose limits shall be determined.
3. An individual shall not receive a planned special exposure such that the additional dose would exceed the following:
 - In a year, the numerical values of the dose limits established in [Table 2-1A](#) or
 - Over the individual's lifetime, five times the numerical values of the dose limits established in [Table 2-1A](#).
4. Prior to a planned special exposure written consent shall be obtained from each individual involved. Each individual shall be:
 - a. Informed of the estimated doses and associated potential risks and specific radiological conditions and other hazards which might be involved in performing the task,
 - b. Informed of the purpose of the planned operations and procedures to be used, and
 - c. Instructed in the measures to be taken to keep the dose ALARA considering other risks that may be present.
5. Records of the conduct of a planned special exposure shall be maintained and a written report submitted within 30 days after the planned special exposure to the approving organizations.
6. The dose from planned special exposures is not to be considered in controlling future occupational dose of the individual under RCM Tables [2-1A](#) and [2-1B](#), but will be appropriately recorded in records and reports.

214 Dose Limits to Minors

No individual under the age of 18 shall be allowed into a Radiologically Controlled Area without the permission of his/her parent or guardian, the Jefferson Lab Director, and the Radiation Control Manager. The annual dose limit to any minor from Jefferson Lab activities is 100 mrem (1mSv) TEDE, and 10% of the annual limits specified in [Table 2-1B](#).

215 Dose Limit for Visitors and Members of the General Population Entering a Controlled Area

1. Members of the general public and visitors to Jefferson Lab entering a Controlled Area shall be limited to an annual radiation dose of 100 mrem from the sum of internal and external radiation sources.
2. An internal dose evaluation program, including a routine bioassay program, shall be conducted for visitors, minors and members of the public entering a Controlled Area who are likely to receive, in 1 year, an intake resulting in a committed effective dose equivalent in excess of 50 percent of the limits stated in [Table 2-1A](#).

216 Embryo/Fetus Dose Limits

1. After a female radiological worker voluntarily notifies her supervisor or Occupational Health & Safety in writing that she is pregnant for the purposes of fetal/embryo dose protection, she is considered a declared pregnant worker, and should be counseled by the Radiation Control Manager (or designee) and Occupational Health & Safety.
2. The dose received by the unborn during the gestation period should be held as low as reasonably achievable and shall not exceed 500 mrem (5 mSv) for a declared pregnant worker. Substantial variation above a uniform exposure rate that would result in the dose to the embryo-fetus exceeding 500 mrem during the gestation period should be avoided. It is assumed that dose to the unborn is the same as the external dose received by the mother.
3. An internal dose evaluation program, including a routine bioassay program, shall be conducted for declared pregnant workers likely to receive an intake resulting in a dose equivalent to the embryo/fetus in excess of 10 percent of the limit stated above.
4. The supervisor, along with Jefferson Lab management and the Radiation Control Manager, should provide the option of a mutually agreeable assignment of work tasks, without loss of pay or promotional opportunity, such that further occupational radiation exposure to the declared pregnant worker is unlikely.
5. If the dose to the embryo/fetus is determined to have already exceeded 500 mrem when a worker declares her pregnancy, the worker shall not be assigned to tasks where additional occupational radiation exposure is likely during the remainder of the gestation period.

217 Special Control Levels

Certain situations require lower individualized exposure control levels. In addition to considering recommendations from Radiation Control Manager and medical officials, the Jefferson Lab Director should obtain advice from professionals in other disciplines such as human resources and legal counsel in establishing Special Control Levels. The Jefferson Lab Director may wish to establish these Special Control Levels with the advice of the Radiation Control Manager, the Occupational Medical Physician, and the Jefferson Lab Radiation Review Panel. Planned Special Exposures carry additional legal notification requirements as indicated in [Article 213](#).



1. A Special Control Level for annual occupational exposure shall be established for each person with a lifetime occupational dose exceeding N rem, where N is the age of the person in years. The Special Control Level should not exceed 1 rem and should allow the person's lifetime occupational dose to approach N rem as additional occupational exposure is received.
2. Although background, therapeutic and diagnostic medical exposures are not included in either personnel radiation dose records or assessment of dose against the limits of Tables [2-1A](#) and [2-1B](#), Special Control Levels may be established as agreed upon by management and the individual.
3. Notification to the Radiation Control Group should be made if any Radiological Worker has been medically administered a long-lived radionuclide. The Radiation Control Group (RCG) shall make a determination if any Special Control Levels should be applied.
4. A Special Control Level shall be established for any individual for whom formal records of previous exposure during the year have not been obtained. This special control is normally 100 mrem.
5. A Special Control Level shall be established for any radiological worker whose previous recorded or estimated exposure for the year is greater than 1 rem. Establishment and approval of this Special Control Level shall be consistent with the ALARA principle and [Article 211](#).

PART 2 Contamination Control and Control Levels

Jefferson Lab maintains appropriate methods of control which prevent the inadvertent transfer of removable contamination to locations outside of radiological areas under normal operating conditions. These methods ensure that contamination is controlled in a manner commensurate with the physical and chemical characteristics of the contaminant, the radionuclides present, and the fixed and removable contamination levels. Control of radioactive contamination is achieved by using engineered and administrative controls to contain contamination at the source, reducing existing areas of contamination, and promptly decontaminating areas that become contaminated.

221 Personnel Contamination Control

1. Personnel exiting Contamination Areas, High Contamination Areas, or Airborne Radioactivity Areas shall be monitored for contamination as required by [Article 338](#).
2. Monitoring for contamination should be performed using monitoring equipment that under laboratory conditions is sensitive enough to detect total contamination to the levels specified in [Table 2-2](#).
3. Personnel found with contamination on their skin or personal clothing, other than gases or natural background radioactivity, should be promptly decontaminated as described in [Article 541](#).

222 Contamination Control Levels

1. A surface shall be considered contaminated if either the removable or total surface radioactivity is detected above the levels in [Table 2-2](#). If an area cannot be decontaminated promptly, then it shall be posted as specified in [Article 234](#).
2. A potentially contaminated item, as used in this Supplement, is defined as an item that has been used or stored in a radiological area that is known or suspected to contain unconfined radioactive material; or an item suspected to be contaminated, based on experience or process knowledge.
3. Surfaces exceeding the values of [Table 2-2](#) for total contamination may be covered with a fixative coating to prevent the spread of contamination. However, reasonable efforts should be made to decontaminate an area before a coating is applied. A fixative coating, other than that used for a temporary work condition, shall not be applied without the approval of the Radiation Control Manager.
4. Volume-activated materials that are not contaminated on the surface are not subject to contamination controls.

223 Airborne Radioactivity Control Levels

1. Personnel should not be exposed unnecessarily to airborne radioactivity. Use of engineered and administrative controls to reduce the potential for internal exposure should be evaluated before allowing personnel, with or without respiratory protection, to enter areas with airborne radioactivity.
2. Occupied areas with airborne concentrations of radioactivity that are greater than, or potentially greater than, a Derived Air Concentration (DAC), or where an individual without respiratory protection could exceed 12 DAC-hours per week, shall be posted as specified in [Article 234](#). For most radionuclides, air containing a Derived Air Concentration results in a committed effective dose equivalent of approximately 100 mrem if inhaled for 40 hours in one work week. Values of Derived Air Concentrations are provided in Appendices [2D](#) and [2E](#).
3. The estimation of internal dose shall be based on bioassay data rather than air concentration values unless bioassay data are:
 - a. unavailable,
 - b. inadequate, or
 - c. internal dose estimates based on representative air concentration values are demonstrated to be as or more accurate.

Table 2-2 Summary of Contamination Values¹

Nuclide (See Note 1)	Removable ^{2,4} (dpm/100 cm ²)	Total (Fixed + Removable) ^{2,3} (dpm/100 cm ²)
U-natural, U-235, U-238 and associated decay products	1,000 ⁷	5,000 ⁷
Transuranics, Ra-226, Ra-228, Th-230, Th-228, Pa-231, Ac-227, I-125, I-129	20	500
Th-nat, Th-232, Sr-90, Ra-223, Ra-224, U-232, I-126, I-131, I-133	200	1,000
Beta-gamma emitters (nuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above. Includes positron emitters and mixed fission products containing Sr-90. ⁵	1,000 beta-gamma	5,000 beta-gamma
Tritium organic compounds, surfaces contaminated by HT, HTO and metal tritide aerosols ⁶	10,000	10 mCi ⁹
Be-7 ⁸	30,000 ⁴	N/A

Notes:

1. The values in this table, with the exception noted in footnote 6 below, apply to radioactive contamination deposited on, but not incorporated into the interior or matrix of, the contaminated item. Where surface contamination by both alpha- and beta-gamma-emitting nuclides exists, the limits established for alpha- and beta-gamma-emitting nuclides apply independently.
2. As used in this table, dpm (disintegrations per minute) means the rate of emission by radioactive material as determined by correcting the counts per minute observed by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.
3. The levels may be averaged over one square meter provided the maximum surface activity in any area of 100 cm² is less than three times the value specified. For purposes of averaging, any square meter of surface shall be considered to be above the surface contamination value if: (1) from measurements of a representative number of sections it is determined that the average contamination level exceeds the applicable value; or (2) it is determined that the sum of the activity of all isolated spots or particles in any 100 cm² area exceeds three times the applicable value.
4. The amount of removable radioactive material per 100 cm² of surface area should be determined by swiping the area with dry filter or soft absorbent paper, applying moderate pressure, and then assessing the amount of radioactive material on the swipe with an appropriate instrument of known efficiency. (Note - The use of dry material may not be appropriate for tritium.) When removable contamination on objects of surface area less than 100 cm² is determined, the activity per unit area shall be based on the actual area and the entire surface shall be wiped. It is not necessary to use swiping tech-



niques to measure removable contamination levels if direct scan surveys indicate that the total residual surface contamination levels are within the limits for removable contamination.

5. This category of radionuclides includes mixed fission products, including the Sr-90 that is present in them. It does not apply to Sr-90 that has been separated from the other fission products or mixtures where the Sr-90 has been enriched.

6. Tritium contamination may diffuse into the volume or matrix of materials. Evaluation of surface contamination shall consider the extent to which such contamination may migrate to the surface in order to ensure the surface contamination value provided in this appendix is not exceeded. Once this contamination migrates to the surface, it may be removable, not fixed; therefore, a "Total" value does not apply.

7. (alpha)

8. For use when Be-7 is suspected or known to be the primary constituent in the contamination. This limit applies to onsite use of equipment and items. Items released from the Controlled Area shall meet requirements for Beta-gamma emitters.

9. Limit for total Tritium (H-3) content for each experimental hall without expressed written consent of the Radiation Control Manager.

PART 3 Posting

231 Posting Requirements

1. Radiological posting shall be used to alert personnel to the presence of radiation and radioactive materials and to aid them in minimizing exposures and preventing the spread of contamination. Signs required by this subpart shall be clearly and conspicuously posted and may include radiological protection instructions. Signs shall contain the standard radiation symbol colored magenta or black on a yellow background. Lettering shall be magenta or black. Standardized signs, as described in written procedures, should be used where practicable.
2. Radiological postings should be displayed only to signify actual or potential radiological conditions. Signs used for training should be clearly marked, such as "For Training Purposes Only."
3. Posted areas should be as small as practicable for efficiency. Postings should be maintained in a legible condition and updated based upon the results of the most recent surveys. If more than one radiological condition (such as contamination and high radiation) exists in the same area, each condition should be identified.
4. In areas of ongoing work activities, the dose rate or range of dose rates should be included on, or in conjunction with, each posting or should be otherwise available in the work area. Entrance points to areas of ongoing radiological work should state basic entry requirements.
5. Rope, tape, chain and similar barriers used to designate the boundaries of posted areas should be yellow and magenta in color. Physical barriers should be placed so that they are clearly visible from all directions and at various elevations. They should not be easily walked over or under, except at identified access points. These barriers shall be set up such that they do not impede the intended use of emergency exits or evacuation routes.
6. Posting of doors should be such that the postings remain visible when doors are open or closed. A radiological posting that signifies the presence of an intermittent radiological condition should include a statement specifying when the radiation is present, such as "CAUTION: RADIATION AREA WHEN RED LIGHT IS ON."
7. The posting and labeling requirements in this subpart may be modified to reflect the special considerations of DOE activities conducted at private residences or businesses. Modifications (to posting requirements) made by Jefferson Lab will provide the same level of protection to individuals as the existing provisions.

232 Posting Controlled Areas

A Controlled Area is any area to which access is managed to protect individuals from exposure to radiation and/or radioactive material. Individuals who enter only Controlled Areas without entering radiological areas or radioactive material areas are not expected to receive a total effective dose equivalent of more than 0.1 rem in a year. Each access point to a Controlled Area is posted, identifying it as a Controlled Area, whenever elevated levels of radiation may be present. For access controls and training requirements, see [Article 331](#).

233 Posting Radiologically Controlled Areas (RCAs)

1. Jefferson Lab has defined RCAs such that any person who works in that area for one year can receive a whole body dose in excess of 100 mrem annual exposure from all pathways (excluding natural background and medical exposures). RCAs shall be marked as such and shall contain information concerning the radiological conditions within. Access to RCAs should be controlled by a variety of means, ranging from simple barriers and warning signs to fully interlocked doors. Within RCAs, occupational exposure is controlled by establishing Radiation Areas, High Radiation Areas, etc. This graded approach increases access requirements on the basis of the increasing potential for radiation exposure.
2. RCAs shall be designated on the basis of estimated or measured radiation dose rate or on account of levels of surface or airborne contamination above specified limits. Subject to the level of supervision and approval by the RCM, relaxation of radiologically controlled area definition in terms of dose rates may be permitted on grounds of infrequent or brief occupation or transient radiation conditions.

234 Posting Radiological Areas

Each access point to radiological areas shall be posted with conspicuous signs bearing the wording provided in this section.

1. Radiation Area

The words "Caution, Radiation Area" shall be posted at each radiation area: Any accessible area where an individual can receive a deep dose in excess of 5 mrem but less than 100 mrem in one hour, at a distance of 30 centimeters from the radiation source or from any surface through which the radiation penetrates.

2. High Radiation Area

The words "Caution, High Radiation Area" or "Danger, High Radiation Area" shall be posted at each high radiation area: Any accessible area where an individual can receive a deep dose in excess of 100 mrem but less than 5 rem in one hour, at a distance of 30 centimeters from the radiation source or from any surface through which the radiation penetrates.

3. Very High Radiation Area

The words "Grave Danger, Very High Radiation Area" shall be posted at each very high radiation area: Any accessible area where an individual can receive a deep dose in excess of 5 rem in one hour, at a distance of 30 centimeters from the radiation source or from any surface through which the radiation penetrates.

4. Hot Spots

Contact readings should be used to determine the presence of hot spots. Hot spots are defined as spots where the dose rate on contact is greater than 100 mrem/hr and at least five times whole body dose rate. Posting of hot spots is not required in areas requiring a job-specific RWP for entry or where constant radiological oversight is in place. It should be noted that contamination is likely to be present on beamline components where the surface readings are greater than 200 mrem/hr.

5. Posting Contamination, High Contamination and Airborne Radioactivity Areas
 - a. Areas accessible to individuals shall be posted to alert personnel to contamination in accordance with [Table 2-4](#) and [Article 231](#).
 - b. The requirement for an RWP should be included either on or in conjunction with each posting as applicable.
 - c. The words “Caution, Airborne Radioactivity Area” shall be posted for any accessible area in which the concentration of airborne radioactivity levels exceed, or are likely to exceed, the DAC value listed in Appendices [2D](#) and [2E](#) or, an individual present in the area without respiratory protection could receive an intake exceeding 12 DAC-hours in a week.

6. Posting Radioactive Material Areas
 - a. Accessible areas where radioactive materials above the values in [Appendix 2F](#) are used, handled or stored shall be posted “CAUTION, RADIOACTIVE MATERIAL.” The posting shall meet the requirements in [Article 231](#).
 - b. Radioactive Material Areas shall be located within Controlled Areas.
 - c. The definition of radioactive material and the requirements for labeling radioactive material are contained in [Chapter 4](#).

7. Posting Radiological Buffer Areas
 - a. A radiological buffer area should be established for contamination control adjacent to any entrance to or exit from a contamination, high contamination, or airborne radioactivity area. The size of the radiological buffer area should be commensurate with the potential for the spread of contamination.
 - b. A radiological buffer area should be established for exposure control adjacent to radiation, high radiation, and very high radiation areas. The boundary for the radiological buffer area should be established to limit radiation doses to general employees to less than 100 millirem per year.
 - c. A radiological buffer area is not required for:
 - High contamination or airborne radioactivity areas that are completely within contamination areas.
 - Inactive contamination, high contamination, or airborne radioactivity areas (i.e., areas to which entry has been prohibited by posting or barricades).
 - Exposure control, if other posted boundaries or controls provide equivalent employee protection.
 - Exposure control, if general employees who are not trained as radiological workers are restricted from unescorted entry to controlled areas.
 - d. The need for radiological buffer areas around radioactive material areas should be evaluated based upon the potential for exposure of unmonitored individuals and the spread of contamination.
 - e. Posting of radiological buffer areas should be in accordance with [Article 231](#) and contain the wording “CAUTION, RADIOLOGICAL BUFFER AREA.”

235 Exceptions to Posting Radiological Areas and Radioactive Material Areas

1. Radioactive Material Areas may be excepted from the posting requirements of [Article 234](#) for periods of less than 8 continuous hours when placed under continuous observation and control of an individual knowledgeable of, and empowered to implement, required access and exposure control measures.
2. Areas may be excepted from the radioactive material area posting requirements of [Article 234](#) when:
 - a. Each item or container of radioactive material is labeled in accordance with [Article 234](#), Paragraph 7 such that individuals entering the area are made aware of the hazard; or
 - b. The radioactive material of concern consists solely of structures or installed components that have been activated (i.e., such as by being exposed to neutron radiation or particles produced in an accelerator).
3. Areas containing only packages received from radioactive material transportation labeled and in non-degraded condition need not be posted in accordance with [Article 234](#) until the packages are monitored in accordance with [Article 432](#).

Table 2-3 Criteria for Posting Radiologically Controlled Areas

Area	Dose Rate Criteria	Posting ^a
Radiation Area	> 0.005 rem in one hour and \leq 0.1 rem in one hour	“CAUTION, RADIATION AREA”
High Radiation Area	> 0.1 rem in one hour and \leq 5 rem in one hour	“DANGER, HIGH RADIATION AREA”
Very High Radiation Area	> 5 rem in one hour	“GRAVE DANGER, VERY HIGH RADIATION AREA”
Hot Spot	> 0.1 rem in one hour; and 5 times general area dose rate or a higher posting requirement	“CAUTION, HOT SPOT”

- a. Appropriate Access requirements should be included on the posting.

Table 2-4 Criteria for Posting Contamination, High Contamination and Airborne Radioactivity Areas

Area	Criteria	Posting
Contamination	Levels (dpm/100 cm ²) > 1 time but \leq 100 times Table 2-2 values	“CAUTION, CONTAMINATION AREA” “RWP Required for Entry”
High Contamination	Levels (dpm/100 cm ²) > 100 times Table 2-2 values	“DANGER, HIGH CONTAMINATION AREA” “RWP Required for Entry”
Airborne Radioactivity	Concentrations (Ci/ml) > DAC value listed in Appendices 2D and 2E .	“CAUTION, AIRBORNE RADIOACTIVITY AREA”



Appendix 2A: Guidelines for Control of Emergency Exposures

In extremely rare cases, emergency exposure to radiation may be necessary to rescue personnel or to protect major property. The recommended dose limits for personnel performing these operations are listed below.

Dose Limit (Whole Body) ^{1,2,3}	Activity Performed	Conditions
5 rem	All	
10 rem	Protecting major property	Where lower dose limit not practicable
25 rem	Lifesaving or protection of large populations	Where lower dose limit not practicable
>25 rem	Lifesaving or protection of large populations	Only on a voluntary basis to personnel fully aware of the risks involved

Notes:

1. The dose limit to the lens of the eye is three times the listed values.
2. The dose limit to the skin of the whole body and the extremities is ten times the listed values.
3. These doses are in addition to and accounted for separately from the doses received under the limits in 10 CFR 835.202.

Appendix 2B: Weighting Factors For Organs And Tissues

Organs or Tissues	Weighting Factor
Gonads	0.25
Breasts	0.15
Red bone marrow	0.12
Lungs	0.12
Thyroid	0.03
Bone surfaces	0.03
Remainder	0.30

Notes:

1. Weighting factors as defined in ICRP Publication 26 and NCRP Report 91 are used to convert organ or tissue dose equivalent to effective dose equivalent for the whole body. The effective dose equivalent is obtained by multiplying the organ dose by the weighting factor. For example, a 5 rem dose to the thyroid would be multiplied by the weighting factor 0.03 to yield 0.15 rem effective dose equivalent.
2. "Remainder" means the five other organs or tissues with the highest dose (e.g. liver, kidney, pancreas, stomach, small intestine and upper large intestine). The weighting factor of 0.3 results from 0.06 for each of the five remainder organs.

Appendix 2C: Non-Uniform Exposure of the Skin

Non-uniform exposures of the skin from photons, beta radiation and radioactive materials on the skin, including hot particles shall be assessed and recorded as specified in the table below:

Area Of Skin Irradiated	Method Of Averaging, Adding To Other Doses Received, And Recording Non-Uniform Skin Dose
$\geq 100 \text{ cm}^2$	Averaged over the 100 cm^2 of skin receiving the maximum dose Added to any uniform dose equivalent also received by the skin Recorded as the annual extremity or skin (shallow) dose equivalent (H)
$< 100 \text{ cm}^2$	Averaged over the 1 cm^2 of skin receiving the maximum dose (D), reduced by the fraction (f) which is the irradiated area in cm^2 divided by 100 cm^2 (i.e. $H=fD$) Added to any uniform dose equivalent also received by the skin Recorded as the annual extremity or skin (shallow) dose equivalent
$< 10 \text{ cm}^2$	Averaged over the 1 cm^2 of skin receiving the maximum dose Not added to any other dose equivalent, extremity or shallow dose equivalent (skin) recorded for the annual dose equivalent Recorded in a person's radiation dose record as a special entry

Appendix 2D: Derived Air Concentrations (DAC) For Controlling Radiation Exposure To Workers At DOE Facilities

The data presented in Appendix 2D are to be used for controlling individual internal doses in accordance with § 835.209, identifying the need for air monitoring in accordance with § 835.403, and identifying and posting airborne radioactivity areas in accordance with § 835.603(d).

The DAC values are given for individual radionuclides. For known mixtures of radionuclides, determine the sum of the ratio of the observed concentration of a particular radionuclide and its corresponding DAC for all radionuclides in the mixture. If this sum exceeds unity (1), then the DAC has been exceeded. For unknown radionuclides, the most restrictive DAC (lowest value) for those isotopes not known to be absent shall be used.

The derived air concentrations (DAC) for limiting radiation exposures through inhalation of radionuclides by workers are listed in this appendix. The values are based on either a stochastic (committed effective dose equivalent) dose limit of 5 rem (0.05 Sv) or a nonstochastic (organ) dose limit of 50 rem (0.5 Sv) per year, whichever is more limiting.

Note: the 15 rem (0.15 Sv) dose limit for the lens of the eye does not appear as a critical organ dose limit.

The columns in this appendix contain the following information: (1) Radionuclide; (2) inhaled air DAC for lung retention class D, W, and Y in units of $\mu\text{Ci/ml}$; (3) inhaled air DAC for lung retention class D, W, and Y in units of Bq/m^3 ; (4) an indication of whether or not the DAC for each class is controlled by the stochastic (effective dose equivalent) or nonstochastic (tissue) dose. The classes D, W, and Y have been established to describe the clearance of inhaled radionuclides from the lung. This classification refers to the approximate length of retention in the pulmonary region. Thus, the range of half-times for retention in the pulmonary region is less than 10 days for class D (days), from 10 to 100 days for class W (weeks), and greater than 100 days for class Y (years). The DACs are listed by radionuclide, in order of increasing atomic mass, and are based on the assumption that the particle size distribution of $1\ \mu\text{m}$ is used. For situations where the particle size distribution is known to differ significantly from $1\ \mu\text{m}$, appropriate corrections can be made to both the estimated dose to workers and the DACs.



Radionuclide	Inhaled Air-Lung Retention Class			Inhaled Air-Lung Retention Class			Stochastic or Organ ¹
	μCi/ml			Bq/m ³			
	D	W	Y	D	W	Y	(D/W/Y)
H-3 (Water) ²	2.E-05	2.E-05	2.E-05	8.E+05	8.E+05	8.E+05	St/St/St
H-3 (Elemental) ²	5.E-01	5.E-01	5.E-01	2.E+10	2.E+10	2.E+10	St/St/St
Be-7	-	9.E-06	8.E-06	-	3.E+05	3.E+05	/St/St
Be-10	-	6.E-08	6.E-09	-	2.E+03	2.E+02	/St/St
C-11 (Org) ²	2.E-04	2.E-04	2.E-04	6.E+06	6.E+06	6.E+06	St/St/St
C-11 (CO) ²	5.E-04	5.E-04	5.E-04	2.E+07	2.E+07	2.E+07	St/St/St
C-11 (CO ₂) ²	3.E-04	3.E-04	3.E-04	1.E+07	1.E+07	1.E+07	St/St/St
C-14 (Org) ²	1.E-06	1.E-06	1.E-06	4.E+07	4.E+04	4.E+07	St/St/St
C-14 (CO) ²	7.E-04	7.E-04	7.E-04	3.E+07	3.E+07	3.E+07	St/St/St
C-14 (CO ₂) ²	9.E-05	9.E-05	9.E-05	3.E+06	3.E+06	3.E+06	St/St/St
F-18	3.E-05	4.E-05	3.E-05	1.E+06	1.E+06	1.E+06	St/St/St
Na-22	3.E-07	-	-	1.E+04	-	-	St/ /
Na-24	2.E-06	-	-	8.E+04	-	-	St/ /
Mg-28	7.E-07	5.E-07	-	3.E+04	2.E+04	-	St/St/
Al-26	3.E-08	3.E-08	-	1.E+03	1.E+03	-	St/St/
Si-31	1.E-05	1.E-05	1.E-05	4.E+05	5.E+05	4.E+05	St/St/St
Si-32	1.E-07	5.E-08	2.E-09	4.E+03	2.E+03	8.E+01	St/St/St
P-32	4.E-07	2.E-07	-	1.E+04	6.E+03	-	St/St/
P-33	3.E-06	1.E-06	-	1.E+05	4.E+04	-	St/St/
S-35	7.E-06	9.E-07	-	3.E+05	3.E+04	-	St/St/
S-35 (Gas)	-	6.E-06	-	-	2.E+05	-	/St/
Cl-36	1.E-06	1.E-07	-	4.E+04	4.E+03	-	St/St/
Cl-38	2.E-05	2.E-05	-	6.E+05	7.E+05	-	St/St/
Cl-39	2.E-05	2.E-05	-	8.E+05	9.E+05	-	St/St/
K-40	2.E-07	-	-	6.E+03	-	-	St/ /
K-42	2.E-06	-	-	7.E+04	-	-	St/ /
K-43	4.E-06	-	-	1.E+05	-	-	St/ /
K-44	3.E-05	-	-	1.E+06	-	-	St/ /



Radionuclide	Inhaled Air-Lung Retention Class			Inhaled Air-Lung Retention Class			Stochastic or Organ ¹
	μCi/ml			Bq/m ³			
	D	W	Y	D	W	Y	(D/W/Y)
K-45	5.E-05	-	-	2.E+06	-	-	St/ /
Ca-41	-	2.E-06	-	-	6.E+04	-	/E/
Ca-45	-	3.E-07	-	-	1.E+04	-	/St/
Ca-47	-	4.E-07	-	-	1.E+04	-	/St/
Sc-43	-	-	1.E-05	-	-	4.E+05	/ /St
Sc-44m	-	-	3.E-07	-	-	1.E+04	/ /St
Sc-44	-	-	5.E-06	-	-	2.E+05	/ /St
Sc-46	-	-	1.E-07	-	-	4.E+03	/ /St
Sc-47	-	-	1.E-06	-	-	5.E+04	/ /St
Sc-48	-	-	6.E-07	-	-	2.E+04	/ /St
Sc-49	-	-	2.E-05	-	-	8.E+05	/ /St
Ti-44	5.E-09	1.E-08	2.E-09	2.E+02	4.E+02	9.E+01	St/St/St
Ti-45	1.E-05	1.E-05	1.E-05	4.E+05	5.E+05	5.E+05	St/St/St
V-47	4.E-05	4.E-05	-	1.E+06	1.E+06	-	St/St/
V-48	4.E-05	3.E-07	-	2.E+04	1.E+04	-	St/St/
V-49	1.E-05	7.E-06	-	5.E+05	3.E+05	-	BS/St/
Cr-48	5.E-06	3.E-06	3.E-06	2.E+05	1.E+05	1.E+05	St/St/St
Cr-49	3.E-05	4.E-05	4.E-05	1.E+06	2.E+06	1.E+06	St/St/St
Cr-51	2.E-05	1.E-05	8.E-06	7.E+05	4.E+05	3.E+05	St/St/St
Mn-51	2.E-05	2.E-05	-	8.E+05	9.E+05	-	St/St/
Mn-52m	4.E-05	4.E-05	-	1.E+06	2.E+06	-	St/St/
Mn-52	5.E-07	4.E-07	-	2.E+04	1.E+04	-	St/St/
Mn-53	5.E-06	5.E-06	-	2.E+05	2.E+05	-	BS/St/
Mn-54	4.E-07	3.E-07	-	1.E+04	1.E+04	-	St/St/
Mn-56	6.E-06	9.E-06	-	2.E+05	3.E+05	-	St/St/
Fe-52	1.E-06	1.E-06	-	5.E+04	4.E+04	-	St/St/
Fe-55	8.E-07	2.E-06	-	3.E+04	6.E+04	-	St/St/
Fe-59	1.E-07	2.E-07	-	5.E+03	8.E+03	-	St/St/



Radionuclide	Inhaled Air-Lung Retention Class			Inhaled Air-Lung Retention Class			Stochastic or Organ ¹
	μCi/ml			Bq/m ³			
	D	W	Y	D	W	Y	(D/W/Y)
Fe-60	3.E-09	8.E-09	-	1.E+02	3.E+02	-	St/St/
Co-55	-	1.E-06	1.E-06	-	4.E+04	4.E+04	/St/St
Co-56	-	1.E-07	8.E-08	-	5.E+03	3.E+03	/St/St
Co-57	-	1.E-06	3.E-07	-	4.E+04	1.E+04	/St/St
Co-58m	-	4.E-05	3.E-05	-	1.E+06	1.E+06	/St/St
Co-58	-	5.E-07	3.E-07	-	2.E+04	1.E+04	/St/St
Co-60m	-	2.E-03	1.E-03	-	6.E+07	4.E+07	/St/St
Co-60	-	7.E-08	1.E-08	-	3.E+03	5.E+02	/St/St
Co-61	-	3.E-05	2.E-05	-	1.E+06	9.E+05	/St/St
Co-62m	-	7.E-05	7.E-05	-	3.E+06	2.E+06	/St/St
Ni-56 (Inorg)	8.E-07	5.E-07	-	3.E+04	2.E+04	-	St/St/
Ni-56 (Vapor)	-	5.E-07	-	-	2.E+04	-	/St/
Ni-57 (Inorg)	2.E-06	1.E-06	-	7.E+04	5.E+04	-	St/St/
Ni-57 (Vapor)	-	3.E-06	-	-	1.E+05	-	/St/
Ni-59 (Inorg)	2.E-06	3.E-06	-	6.E+04	1.E+05	-	St/St/
Ni-59 (Vapor)	-	8.E-07	-	-	3.E+04	-	/St/
Ni-63 (Inorg)	7.E-07	1.E-06	-	3.E+04	4.E+04	-	St/St/
Ni-63 (Vapor)	-	3.E-07	-	-	1.E+04	-	/St/
Ni-65 (Inorg)	1.E-05	1.E-05	-	4.E+05	5.E+05	-	St/St/
Ni-65 (Vapor)	-	7.E-06	-	-	3.E+05	-	/St/
Ni-66 (Inorg)	7.E-07	3.E-07	-	3.E+04	1.E+04	-	St/St/
Ni-66 (Vapor)	-	1.E-06	-	-	5.E+04	-	/St/
Cu-60	4.E-05	5.E-05	4.E-05	1.E+06	2.E+06	2.E+06	St/St/St
Cu-61	1.E-05	2.E-05	1.E-05	5.E+05	6.E+05	5.E+05	St/St/St
Cu-64	1.E-05	1.E-05	9.E-06	5.E+05	4.E+05	3.E+05	St/St/St
Cu-67	3.E-06	2.E-06	2.E-06	1.E+05	8.E+04	7.E+04	St/St/St
Zn-62	-	-	1.E-06	-	-	4.E+04	/ /St
Zn-63	-	-	3.E-05	-	-	1.E+06	/ /St



Radionuclide	Inhaled Air-Lung Retention Class			Inhaled Air-Lung Retention Class			Stochastic or Organ ¹
	μCi/ml			Bq/m ³			
	D	W	Y	D	W	Y	(D/W/Y)
Zn-65	-	-	1.E-07	-	-	4.E+03	/ /St
Zn-69m	-	-	3.E-06	-	-	1.E+05	/ /St
Zn-69	-	-	6.E-05	-	-	2.E+06	/ /St
Zn-71m	-	-	7.E-06	-	-	3.E+05	/ /St
Zn-72	-	-	5.E-07	-	-	2.E+04	/ /St
Ga-65	7.E-05	8.E-05	-	3.E+06	3.E+06	-	St/St/
Ga-66	1.E-06	1.E-06	-	5.E+04	5.E+04	-	St/St/
Ga-67	6.E-06	4.E-06	-	2.E+05	2.E+05	-	St/St/
Ga-68	2.E-05	2.E-05	-	6.E+05	8.E+05	-	St/St/
Ga-70	7.E-05	8.E-05	-	3.E+06	3.E+06	-	St/St/
Ga-72	2.E-06	1.E-06	-	6.E+04	5.E+04	-	St/St/
Ga-73	6.E-06	6.E-06	-	2.E+05	2.E+05	-	St/St/
Ge-66	1.E-05	8.E-06	-	4.E+05	3.E+05	-	St/St/
Ge-67	4.E-05	4.E-05	-	1.E+06	2.E+06	-	St/St/
Ge-68	2.E-06	4.E-08	-	6.E+04	2.E+03	-	St/St/
Ge-69	6.E-06	3.E-06	-	2.E+05	1.E+05	-	St/St/
Ge-71	2.E-04	2.E-05	-	7.E+06	6.E+05	-	St/St/
Ge-75	3.E-05	3.E-05	-	1.E+06	1.E+06	-	St/St/
Ge-77	4.E-06	2.E-06	-	2.E+05	9.E+04	-	St/St/
Ge-78	9.E-06	9.E-06	-	4.E+05	3.E+05	-	St/St/
As-69	-	5.E-05	-	-	2.E+06	-	/St/
As-70	-	2.E-05	-	-	8.E+05	-	/St/
As-71	-	2.E-06	-	-	7.E+04	-	/St/
As-72	-	6.E-07	-	-	2.E+04	-	/St/
As-73	-	7.E-07	-	-	3.E+04	-	/St/
As-74	-	3.E-07	-	-	1.E+04	-	/St/
As-76	-	6.E-07	-	-	2.E+04	-	/St/
As-77	-	2.E-06	-	-	8.E+04	-	/St/



Radionuclide	Inhaled Air-Lung Retention Class			Inhaled Air-Lung Retention Class			Stochastic or Organ ¹
	μCi/ml			Bq/m ³			
	D	W	Y	D	W	Y	(D/W/Y)
As-78	-	9.E-06	-	-	3.E+05	-	/St/
Se-70	1.E-05	2.E-05	-	6.E+05	7.E+05	-	St/St/
Se-73m	6.E-05	6.E-05	-	2.E+06	2.E+06	-	St/St/
Se-73	6.E-06	7.E-06	-	2.E+05	2.E+05	-	St/St/
Se-75	3.E-07	3.E-07	-	1.E+04	9.E+03	-	St/St/
Se-79	3.E-07	2.E-07	-	1.E+04	9.E+03	-	St/St/
Se-81m	3.E-05	3.E-05	-	1.E+06	1.E+06	-	St/St/
Se-81	9.E-05	1.E-04	-	3.E+06	4.E+06	-	St/St/
Se-83	5.E-05	5.E-05	-	2.E+06	2.E+06	-	St/St/
Br-74m	1.E-05	2.E-05	-	6.E+05	6.E+05	-	St/St/
Br-74	3.E-05	3.E-05	-	1.E+06	1.E+06	-	St/St/
Br-75	2.E-05	2.E-05	-	7.E+05	8.E+05	-	St/St/
Br-76	2.E-06	2.E-06	-	7.E+04	7.E+04	-	St/St/
Br-77	1.E-05	8.E-06	-	4.E+05	3.E+05	-	St/St/
Br-80m	7.E-06	6.E-06	-	3.E+05	2.E+05	-	St/St/
Br-80	8.E-05	9.E-05	-	3.E+06	3.E+06	-	St/St/
Br-82	2.E-06	2.E-06	-	6.E+04	6.E+04	-	St/St/
Br-83	3.E-05	3.E-05	-	1.E+06	1.E+06	-	St/St/
Br-84	2.E-05	3.E-05	-	9.E+05	1.E+06	-	St/St/
Rb-79	5.E-05	-	-	2.E+06	-	-	St/ /
Rb-81m	1.E-04	-	-	5.E+06	-	-	St/ /
Rb-81	2.E-05	-	-	8.E+05	-	-	St/ /
Rb-82m	7.E-06	-	-	3.E+05	-	-	St/ /
Rb-83	4.E-07	-	-	2.E+04	-	-	St/ /
Rb-84	3.E-07	-	-	1.E+04	-	-	St/ /
Rb-86	3.E-07	-	-	1.E+04	-	-	St/ /
Rb-87	6.E-07	-	-	2.E+04	-	-	St/ /
Rb-88	3.E-05	-	-	1.E+06	-	-	St/ /



Radionuclide	Inhaled Air-Lung Retention Class			Inhaled Air-Lung Retention Class			Stochastic or Organ ¹
	μCi/ml			Bq/m ³			
	D	W	Y	D	W	Y	(D/W/Y)
Rb-89	6.E-05	-	-	2.E+06	-	-	St/ /
Sr-80	5.E-06	-	5.E-06	2.E+05	-	2.E+05	St/ /St
Sr-81	3.E-05	-	3.E-05	1.E+06	-	1.E+06	St/ /St
Sr-83	3.E-06	-	2.E-06	1.E+05	-	5.E+04	St/ /St
Sr-85m	3.E-04	-	3.E-04	9.E+06	-	1.E+07	St/ /St
Sr-85	1.E-06	-	7.E-07	4.E+04	-	2.E+04	St/ /St
Sr-87m	5.E-05	-	6.E-05	2.E+06	-	2.E+06	St/ /St
Sr-89	3.E-07	-	6.E-08	1.E+04	-	2.E+03	St/ /St
Sr-90	8.E-09	-	2.E-09	3.E+02	-	6.E+01	BS/ /St
Sr-91	2.E-06	-	1.E-06	9.E+04	-	5.E+04	St/ /St
Sr-92	4.E-06	-	3.E-06	1.E+05	-	1.E+05	St/ /St
Y-86m	-	2.E-05	2.E-05	-	9.E+05	9.E+05	/St/St
Y-86	-	1.E-06	1.E-06	-	5.E+04	5.E+04	/St/St
Y-87	-	1.E-06	1.E-06	-	5.E+04	5.E+04	/St/St
Y-88	-	1.E-07	1.E-07	-	4.E+03	4.E+03	/St/St
Y-90m	-	5.E-06	5.E-06	-	2.E+05	2.E+05	/St/St
Y-90	-	3.E-07	2.E-07	-	1.E+04	9.E+03	/St/St
Y-91m	-	1.E-04	7.E-05	-	4.E+06	3.E+06	/St/St
Y-91	-	7.E-08	5.E-08	-	3.E+03	2.E+03	/St/St
Y-92	-	3.E-06	3.E-06	-	1.E+05	1.E+05	/St/St
Y-93	-	1.E-06	1.E-06	-	4.E+04	4.E+04	/St/St
Y-94	-	3.E-05	3.E-05	-	1.E+06	1.E+06	/St/St
Y-95	-	6.E-05	6.E-05	-	2.E+06	2.E+06	/St/St
Zr-86	2.E-06	1.E-06	1.E-06	6.E+04	4.E+04	4.E+04	St/St/St
Zr-88	9.E-08	2.E-07	1.E-07	3.E+03	7.E+03	5.E+03	St/St/St
Zr-89	2.E-06	1.E-06	1.E-06	5.E+04	4.E+04	4.E+04	St/St/St
Zr-93	3.E-09	1.E-08	2.E-08	1.E+02	4.E+02	9.E+02	BS/BS/BS
Zr-95	6.E-08	2.E-07	1.E-07	2.E+03	6.E+03	4.E+03	BS/St/St



Radionuclide	Inhaled Air-Lung Retention Class			Inhaled Air-Lung Retention Class			Stochastic or Organ ¹
	μCi/ml			Bq/m ³			
	D	W	Y	D	W	Y	(D/W/Y)
Zr-97	8.E-07	6.E-07	5.E-07	3.E+04	2.E+04	2.E+04	St/St/St
Nb-88	-	1.E-04	9.E-05	-	4.E+06	3.E+06	/St/St
Nb-89 (66 min)	-	2.E-05	2.E-05	-	6.E+05	6.E+05	/St/St
Nb-89 (122 min)	-	8.E-06	7.E-06	-	3.E+05	2.E+05	/St/St
Nb-90	-	1.E-06	1.E-06	-	4.E+04	4.E+04	/St/St
Nb-93m	-	5.E-07	7.E-08	-	2.E+04	3.E+03	/St/St
Nb-94	-	8.E-08	6.E-09	-	3.E+03	2.E+02	/St/St
Nb-95m	-	1.E-06	9.E-07	-	4.E+04	4.E+04	/St/St
Nb-95	-	5.E-07	5.E-07	-	2.E+04	2.E+04	/St/St
Nb-96	-	1.E-06	1.E-06	-	4.E+04	4.E+04	/St/St
Nb-97	-	3.E-05	3.E-05	-	1.E+06	1.E+06	/St/St
Nb-98	-	2.E-05	2.E-05	-	8.E+05	8.E+05	/St/St
Mo-90	3.E-06	-	2.E-06	1.E+05	-	7.E+04	St/ /St
Mo-93m	7.E-06	-	6.E-06	3.E+05	-	2.E+05	St/ /St
Mo-93	2.E-06	-	7.E-08	8.E+04	-	3.E+03	St/ /St
Mo-99	1.E-06	-	6.E-07	4.E+04	-	2.E+04	St/ /St
Mo-101	6.E-05	-	6.E-05	2.E+06	-	2.E+06	St/ /St
Tc-93m	7.E-05	1.E-04	-	2.E+06	5.E+06	-	St/St/
Tc-93	3.E-05	4.E-05	-	1.E+06	2.E+06	-	St/St/
Tc-94m	2.E-05	2.E-05	-	7.E+05	9.E+05	-	St/St/
Tc-94	8.E-06	1.E-05	-	3.E+05	4.E+05	-	St/St/
Tc-96m	1.E-04	1.E-04	-	4.E+06	4.E+06	-	St/St/
Tc-96	1.E-06	9.E-07	-	5.E+04	3.E+04	-	St/St/
Tc-97m	3.E-06	5.E-07	-	1.E+05	2.E+04	-	SW/St/
Tc-97	2.E-05	2.E-06	-	8.E+05	9.E+04	-	St/St/
Tc-98	7.E-07	1.E-07	-	3.E+04	5.E+03	-	St/St/
Tc-99m	6.E-05	1.E-04	-	2.E+06	4.E+06	-	St/St/
Tc-99	2.E-06	3.E-07	-	8.E+04	1.E+04	-	SW/St/



Radionuclide	Inhaled Air-Lung Retention Class			Inhaled Air-Lung Retention Class			Stochastic or Organ ¹
	μCi/ml			Bq/m ³			
	D	W	Y	D	W	Y	(D/W/Y)
Tc-101	1.E-04	2.E-04	-	5.E+06	6.E+06	-	St/St/
Tc-104	3.E-05	4.E-05	-	1.E+06	1.E+06	-	St/St/
Ru-94	2.E-05	3.E-05	2.E-05	7.E+05	1.E+06	9.E+05	St/St/St
Ru-97	8.E-06	5.E-06	5.E-06	3.E+05	2.E+05	2.E+05	St/St/St
Ru-103	7.E-07	4.E-07	3.E-07	3.E+04	2.E+04	1.E+04	St/St/St
Ru-105	6.E-06	6.E-06	5.E-06	2.E+05	2.E+05	2.E+05	St/St/St
Ru-106	4.E-08	2.E-08	5.E-09	1.E+03	8.E+02	2.E+02	St/St/St
Rh-99m	2.E-05	3.E-05	3.E-05	9.E+05	1.E+06	1.E+06	St/St/St
Rh-99	1.E-06	9.E-07	8.E-07	5.E+04	3.E+04	3.E+04	St/St/St
Rh-100	2.E-06	2.E-06	2.E-06	8.E+04	6.E+04	6.E+04	St/St/St
Rh-101m	5.E-06	3.E-06	3.E-06	2.E+05	1.E+05	1.E+05	St/St/St
Rh-101	2.E-07	3.E-07	7.E-08	8.E+03	1.E+04	2.E+03	St/St/St
Rh-102m	2.E-07	2.E-07	5.E-08	8.E+03	6.E+03	2.E+03	St/St/St
Rh-102	4.E-08	7.E-08	2.E-08	1.E+03	3.E+03	9.E+02	St/St/St
Rh-103m	4.E-04	5.E-04	5.E-04	2.E+07	2.E+07	2.E+07	St/St/St
Rh-105	5.E-06	3.E-06	2.E-06	2.E+05	1.E+05	9.E+04	St/St/St
Rh-106m	1.E-05	1.E-05	1.E-05	4.E+05	6.E+05	5.E+05	St/St/St
Rh-107	1.E-04	1.E-04	1.E-04	4.E+06	4.E+06	4.E+06	St/St/St
Pd-100	6.E-07	5.E-07	6.E-07	2.E+04	2.E+04	2.E+04	St/St/St
Pd-101	1.E-05	1.E-05	1.E-05	5.E+05	5.E+05	5.E+05	St/St/St
Pd-103	3.E-06	2.E-06	1.E-06	1.E+05	7.E+04	5.E+04	St/St/St
Pd-107	9.E-06	3.E-06	2.E-07	3.E+05	1.E+05	6.E+03	K/St/St
Pd-109	3.E-06	2.E-06	2.E-06	1.E+05	8.E+04	7.E+04	St/St/St
Ag-102	8.E-05	9.E-05	8.E-05	3.E+06	3.E+06	3.E+06	St/St/St
Ag-103	4.E-05	6.E-05	5.E-05	2.E+06	2.E+06	2.E+06	St/St/St
Ag-104m	4.E-05	5.E-05	5.E-05	2.E+06	2.E+06	2.E+06	St/St/St
Ag-104	3.E-05	6.E-05	6.E-05	1.E+06	2.E+06	2.E+06	St/St/St
Ag-105	4.E-07	7.E-07	7.E-07	2.E+04	3.E+04	3.E+04	St/St/St



Radionuclide	Inhaled Air-Lung Retention Class			Inhaled Air-Lung Retention Class			Stochastic or Organ ¹
	μCi/ml			Bq/m ³			
	D	W	Y	D	W	Y	(D/W/Y)
Ag-106m	3.E-07	4.E-07	4.E-07	1.E+04	1.E+04	1.E+04	St/St/St
Ag-106	7.E-05	8.E-05	8.E-05	3.E+06	3.E+06	3.E+06	St/St/St
Ag-108m	8.E-08	1.E-07	1.E-08	3.E+03	4.E+03	4.E+02	St/St/St
Ag-110m	6.E-08	8.E-08	4.E-08	2.E+03	3.E+03	1.E+03	St/St/St
Ag-111	7.E-07	4.E-07	4.E-07	2.E+04	1.E+04	1.E+04	L/St/St
Ag-112	3.E-06	4.E-06	4.E-06	1.E+05	2.E+05	1.E+05	St/St/St
Ag-115	4.E-05	4.E-05	3.E-05	1.E+06	1.E+06	1.E+06	St/St/St
Cd-104	3.E-05	5.E-05	5.E-05	1.E+06	2.E+06	2.E+06	St/St/St
Cd-107	2.E-05	2.E-05	2.E-05	8.E+05	9.E+05	8.E+05	St/St/St
Cd-109	1.E-08	5.E-08	5.E-08	5.E+02	2.E+03	2.E+03	K/K/St
Cd-113m	1.E-09	4.E-09	5.E-09	4.E+01	1.E+02	2.E+02	K/K/St
Cd-113	9.E-10	3.E-09	6.E-09	4.E+01	1.E+02	2.E+02	K/K/St
Cd-115m	2.E-08	5.E-08	6.E-08	8.E+02	2.E+03	2.E+03	K/St/St
Cd-115	6.E-07	5.E-07	6.E-07	2.E+04	2.E+04	2.E+04	St/St/St
Cd-117m	5.E-06	7.E-06	6.E-06	2.E+05	3.E+05	2.E+05	St/St/St
Cd-117	5.E-06	7.E-06	6.E-06	2.E+05	3.E+05	2.E+05	St/St/St
In-109	2.E-05	3.E-05	-	7.E+05	1.E+06	-	St/St/
In-110 (69 min)	2.E-05	2.E-05	-	7.E+05	9.E+05	-	St/St/
In-110 (5 h)	7.E-06	8.E-06	-	3.E+05	3.E+05	-	St/St/
In-111	3.E-06	3.E-06	-	1.E+05	1.E+05	-	St/St/
In-112	3.E-04	3.E-04	-	1.E+07	1.E+07	-	St/St/
In-113m	6.E-05	8.E-05	-	2.E+06	3.E+06	-	St/St/
In-114m	3.E-08	4.E-08	-	1.E+03	2.E+03	-	St/St/
In-115m	2.E-05	2.E-05	-	7.E+05	7.E+05	-	St/St/
In-115	6.E-10	2.E-09	-	2.E+01	8.E+01	-	St/St/
In-116m	3.E-05	5.E-05	-	1.E+06	2.E+06	-	St/St/
In-117m	1.E-05	2.E-05	-	5.E+05	7.E+05	-	St/St/
In-117	7.E-05	9.E-05	-	3.E+06	3.E+06	-	St/St/



Radionuclide	Inhaled Air-Lung Retention Class			Inhaled Air-Lung Retention Class			Stochastic or Organ ¹
	μCi/ml			Bq/m ³			
	D	W	Y	D	W	Y	(D/W/Y)
In-119m	5.E-05	6.E-05	-	2.E+06	2.E+06	-	St/St/
Sn-110	5.E-06	5.E-06	-	2.E+05	2.E+05	-	St/St/
Sn-111	9.E-05	1.E-04	-	4.E+06	4.E+06	-	St/St/
Sn-113	5.E-07	2.E-07	-	2.E+04	9.E+03	-	St/St/
Sn-117m	5.E-07	6.E-07	-	2.E+04	2.E+04	-	BS/St/
Sn-119m	1.E-06	4.E-07	-	4.E+04	1.E+04	-	St/St/
Sn-121m	4.E-07	2.E-07	-	1.E+04	9.E+03	-	St/St/
Sn-121	6.E-06	5.E-06	-	2.E+05	2.E+05	-	St/St/
Sn-123m	5.E-05	6.E-05	-	2.E+06	2.E+06	-	St/St/
Sn-123	3.E-07	7.E-08	-	1.E+04	3.E+03	-	St/St/
Sn-125	4.E-07	2.E-07	-	1.E+04	5.E+03	-	St/St/
Sn-126	2.E-08	3.E-08	-	9.E+02	1.E+03	-	St/St/
Sn-127	8.E-06	8.E-06	-	3.E+05	3.E+05	-	St/St/
Sn-128	1.E-05	1.E-05	-	4.E+05	6.E+05	-	St/St/
Sb-115	1.E-04	1.E-04	-	4.E+06	5.E+06	-	St/St/
Sb-116m	3.E-05	6.E-05	-	1.E+06	2.E+06	-	St/St/
Sb-116	1.E-04	1.E-04	-	4.E+06	5.E+06	-	St/St/
Sb-117	9.E-05	1.E-04	-	3.E+06	4.E+06	-	St/St/
Sb-118m	8.E-06	9.E-06	-	3.E+05	3.E+05	-	St/St/
Sb-119	2.E-05	1.E-05	-	7.E+05	4.E+05	-	St/St/
Sb-120 (16 min)	2.E-04	2.E-04	-	7.E+06	8.E+06	-	St/St/
Sb-120 (6 d)	9.E-07	6.E-07	-	3.E+04	2.E+04	-	St/St/
Sb-122	1.E-06	4.E-07	-	4.E+04	2.E+04	-	St/St/
Sb-124m	3.E-04	3.E-04	-	1.E+07	9.E+06	-	St/St/
Sb-124	4.E-07	1.E-07	-	1.E+04	4.E+03	-	St/St/
Sb-125	1.E-06	2.E-07	-	4.E+04	8.E+03	-	St/St/
Sb-126m	8.E-05	8.E-05	-	3.E+06	3.E+06	-	St/St/
Sb-126	4.E-07	2.E-07	-	2.E+04	8.E+03	-	St/St/



Radionuclide	Inhaled Air-Lung Retention Class			Inhaled Air-Lung Retention Class			Stochastic or Organ ¹
	μCi/ml			Bq/m ³			
	D	W	Y	D	W	Y	(D/W/Y)
Sb-127	9.E-07	4.E-07	-	3.E+04	1.E+04	-	St/St/
Sb-128 (9 h)	2.E-06	1.E-06	-	6.E+04	5.E+04	-	St/St/
Sb-128 (10 min)	2.E-04	2.E-04	-	6.E+06	7.E+06	-	St/St/
Sb-129	4.E-06	4.E-06	-	1.E+05	1.E+05	-	St/St/
Sb-130	3.E-05	3.E-05	-	1.E+06	1.E+06	-	St/St/
Sb-131	1.E-05	1.E-05	-	4.E+05	4.E+05	-	T/T/
Te-116	9.E-06	1.E-05	-	3.E+05	5.E+05	-	St/St/
Te-121m	8.E-08	2.E-07	-	3.E+03	6.E+03	-	BS/St/
Te-121	2.E-06	1.E-06	-	7.E+04	5.E+04	-	St/St/
Te-123m	9.E-08	2.E-07	-	3.E+03	8.E+03	-	BS/St/
Te-123	8.E-08	2.E-07	-	3.E+03	7.E+03	-	BS/BS/
Te-125m	2.E-07	3.E-07	-	7.E+03	1.E+04	-	BS/St/
Te-127m	1.E-07	1.E-07	-	4.E+03	4.E+03	-	BS/St/
Te-127	9.E-06	7.E-06	-	4.E+05	3.E+05	-	St/St/
Te-129m	3.E-07	1.E-07	-	1.E+04	4.E+03	-	St/St/
Te-129	3.E-05	3.E-05	-	1.E+06	1.E+06	-	St/St/
Te-131m	2.E-07	2.E-07	-	6.E+03	6.E+03	-	T/T/
Te-131	2.E-06	2.E-06	-	8.E+04	8.E+04	-	T/T/
Te-132	9.E-08	9.E-08	-	4.E+03	3.E+03	-	T/T/
Te-133m	2.E-06	2.E-06	-	8.E+04	8.E+04	-	T/T/
Te-133	9.E-06	9.E-06	-	4.E+05	4.E+05	-	T/T/
Te-134	1.E-05	1.E-05	-	4.E+05	4.E+05	-	T/T/
I-120m	9.E-06	-	-	3.E+05	-	-	St/ /
I-120	4.E-06	-	-	1.E+05	-	-	T/ /
I-121	7.E-06	-	-	3.E+05	-	-	T/ /
I-123	3.E-06	-	-	1.E+05	-	-	T/ /
I-124	3.E-08	-	-	1.E+03	-	-	T/ /
I-125	3.E-08	-	-	1.E+03	-	-	T/ /



Radionuclide	Inhaled Air-Lung Retention Class			Inhaled Air-Lung Retention Class			Stochastic or Organ ¹
	μCi/ml			Bq/m ³			
	D	W	Y	D	W	Y	(D/W/Y)
I-126	1.E-08	-	-	5.E+02	-	-	T/ /
I-128	5.E-05	-	-	2.E+06	-	-	St/ /
I-129	4.E-09	-	-	1.E+02	-	-	T/ /
I-130	3.E-07	-	-	1.E+04	-	-	T/ /
I-131	2.E-08	-	-	7.E+02	-	-	T/ /
I-132m	4.E-06	-	-	1.E+05	-	-	T/ /
I-132	3.E-06	-	-	1.E+05	-	-	T/ /
I-133	1.E-07	-	-	4.E+03	-	-	T/ /
I-134	2.E-05	-	-	7.E+05	-	-	E/ /
I-135	7.E-07	-	-	2.E+04	-	-	T/ /
Cs-125	6.E-05	-	-	2.E+06	-	-	St/ /
Cs-127	4.E-05	-	-	2.E+06	-	-	St/ /
Cs-129	1.E-05	-	-	5.E+05	-	-	St/ /
Cs-130	8.E-05	-	-	3.E+06	-	-	St/ /
Cs-131	1.E-05	-	-	5.E+05	-	-	St/ /
Cs-132	2.E-06	-	-	6.E+04	-	-	St/ /
Cs-134m	6.E-05	-	-	2.E+06	-	-	St/ /
Cs-134	4.E-08	-	-	2.E+03	-	-	St/ /
Cs-135m	8.E-05	-	-	3.E+06	-	-	St/ /
Cs-135	5.E-07	-	-	2.E+04	-	-	St/ /
Cs-136	3.E-07	-	-	1.E+04	-	-	St/ /
Cs-137	7.E-08	-	-	2.E+03	-	-	St/ /
Cs-138	2.E-05	-	-	9.E+05	-	-	St/ /
Ba-126	6.E-06	-	-	2.E+05	-	-	St/ /
Ba-128	7.E-07	-	-	3.E+04	-	-	St/ /
Ba-131m	6.E-04	-	-	2.E+07	-	-	St/ /
Ba-131	3.E-06	-	-	1.E+05	-	-	St/ /
Ba-133m	4.E-06	-	-	1.E+05	-	-	St/ /



Radionuclide	Inhaled Air-Lung Retention Class			Inhaled Air-Lung Retention Class			Stochastic or Organ ¹
	µCi/ml			Bq/m ³			
	D	W	Y	D	W	Y	(D/W/Y)
Ba-133	3.E-07	-	-	1.E+04	-	-	St/ /
Ba-135m	5.E-06	-	-	2.E+05	--	-	St/ /
Ba-139	1.E-05	-	-	5.E+05	-	-	St/ /
Ba-140	6.E-07	-	-	2.E+04	-	-	St/ /
Ba-141	3.E-05	-	-	1.E+06	-	-	St/ /
Ba-142	6.E-05	-	-	2.E+06	-	-	St/ /
La-131	5.E-05	7.E-05	-	2.E+06	3.E+06	-	St/St/
La-132	4.E-06	5.E-06	-	2.E+05	2.E+05	-	St/St/
La-135	4.E-05	4.E-05	-	2.E+06	2.E+06	-	St/St/
La-137	3.E-08	1.E-07	-	1.E+03	4.E+03	-	L/E/
La-138	2.E-09	6.E-09	-	5.E+01	2.E+02	-	St/St/
La-140	6.E-07	5.E-07	-	2.E+04	2.E+04	-	St/St/
La-141	4.E-06	5.E-06	-	1.E+05	2.E+05	-	St/St/
La-142	9.E-06	1.E-05	-	4.E+05	5.E+05	-	St/St/
La-143	4.E-05	4.E-05	-	2.E+06	1.E+06	-	St/St/
Ce-134	-	3.E-07	3.E-07	-	1.E+04	1.E+04	/St/St
Ce-135	-	2.E-06	2.E-06	-	6.E+04	5.E+04	/St/St
Ce-137m	-	2.E-06	2.E-06	-	7.E+04	6.E+04	/St/St
Ce-137	-	6.E-05	5.E-05	-	2.E+06	2.E+06	/St/St
Ce-139	-	3.E-07	3.E-07	-	1.E+04	1.E+04	/St/St
Ce-141	-	3.E-07	2.E-07	-	1.E+04	9.E+03	/St/St
Ce-143	-	8.E-07	7.E-07	-	3.E+04	2.E+04	/St/St
Ce-144	-	1.E-08	6.E-09	-	4.E+02	2.E+02	/St/St
Pr-136	-	1.E-04	9.E-05	-	4.E+06	4.E+06	/St/St
Pr-137	-	6.E-05	6.E-05	-	2.E+06	2.E+06	/St/St
Pr-138m	-	2.E-05	2.E-05	-	8.E+05	7.E+05	/St/St
Pr-139	-	5.E-05	5.E-05	-	2.E+06	2.E+06	/St/St
Pr-142m	-	7.E-05	6.E-05	-	3.E+06	2.E+06	/St/St



Radionuclide	Inhaled Air-Lung Retention Class			Inhaled Air-Lung Retention Class			Stochastic or Organ ¹
	μCi/ml			Bq/m ³			
	D	W	Y	D	W	Y	(D/W/Y)
Pr-142	-	8.E-07	8.E-07	-	3.E+04	3.E+04	/St/St
Pr-143	-	3.E-07	3.E-07	-	1.E+04	1.E+04	/St/St
Pr-144	-	5.E-05	5.E-05	-	2.E+06	2.E+06	/St/St
Pr-145	-	4.E-06	3.E-06	-	1.E+05	1.E+05	/St/St
Pr-147	-	8.E-05	8.E-05	-	3.E+06	3.E+06	/St/St
Nd-136	-	2.E-05	2.E-05	-	9.E+05	8.E+05	/St/St
Nd-138	-	3.E-06	2.E-06	-	1.E+05	8.E+04	/St/St
Nd-139m	-	7.E-06	6.E-06	-	3.E+05	2.E+05	/St/St
Nd-139	-	1.E-04	1.E-04	-	5.E+06	4.E+06	/St/St
Nd-141	-	3.E-04	3.E-04	-	1.E+07	9.E+06	/St/St
Nd-147	-	4.E-07	3.E-07	-	2.E+04	1.E+04	/St/St
Nd-149	-	1.E-05	1.E-05	-	4.E+05	4.E+05	/St/St
Nd-151	-	8.E-05	8.E-05	-	3.E+06	3.E+06	/St/St
Pm-141	-	8.E-05	7.E-05	-	3.E+06	3.E+06	/St/St
Pm-143	-	3.E-07	3.E-07	-	9.E+03	1.E+04	/St/St
Pm-144	-	5.E-08	5.E-08	-	2.E+03	2.E+03	/St/St
Pm-145	-	7.E-08	8.E-08	-	3.E+03	3.E+03	/BS/St
Pm-146	-	2.E-08	2.E-08	-	8.E+02	7.E+02	/St/St
Pm-147	-	6.E-08	6.E-08	-	2.E+03	2.E+03	/BS/St
Pm-148m	-	1.E-07	1.E-07	-	5.E+03	5.E+03	/St/St
Pm-148	-	2.E-07	2.E-07	-	8.E+03	8.E+03	/St/St
Pm-149	-	8.E-07	8.E-07	-	3.E+04	3.E+04	/St/St
Pm-150	-	8.E-06	7.E-06	-	3.E+05	3.E+05	/St/St
Pm-151	-	2.E-06	1.E-06	-	6.E+04	5.E+04	/St/St
Sm-141m	-	4.E-05	-	-	2.E+06	-	/St/
Sm-141	-	7.E-05	-	-	3.E+06	-	/St/
Sm-142	-	1.E-05	-	-	4.E+05	-	/St/
Sm-145	-	2.E-07	-	-	8.E+03	-	/St/



Radionuclide	Inhaled Air-Lung Retention Class			Inhaled Air-Lung Retention Class			Stochastic or Organ ¹
	μCi/ml			Bq/m ³			
	D	W	Y	D	W	Y	(D/W/Y)
Sm-146	-	1.E-11	-	-	6.E-01	-	/BS/
Sm-147	-	2.E-11	-	-	6.E-01	-	/BS/
Sm-151	-	4.E-08	-	-	2.E+03	-	/BS/
Sm-153	-	1.E-06	-	-	4.E+04	-	/St/
Sm-155	-	9.E-05	-	-	3.E+06	-	/St/
Sm-156	-	4.E-06	-	-	1.E+05	-	/St/
Eu-145	-	8.E-07	-	-	3.E+04	-	/St/
Eu-146	-	5.E-07	-	-	2.E+04	-	/St/
Eu-147	-	7.E-07	-	-	3.E+04	-	/St/
Eu-148	-	2.E-07	-	-	6.E+03	-	/St/
Eu-149	-	1.E-06	-	-	5.E+04	-	/St/
Eu-150 (12 h)	-	3.E-06	-	-	1.E+05	-	/St/
Eu-150 (34 yr)	-	8.E-09	-	-	3.E+02	-	/St/
Eu-152m	-	3.E-06	-	-	1.E+05	-	/St/
Eu-152	-	1.E-08	-	-	4.E+02	-	/St/
Eu-154	-	8.E-09	-	-	3.E+02	-	/St/
Eu-155	-	4.E-08	-	-	1.E+03	-	/BS/
Eu-156	-	2.E-07	-	-	7.E+03	-	/St/
Eu-157	-	2.E-06	-	-	7.E+04	-	/St/
Eu-158	-	2.E-5	-	-	9.E+05	-	/St/
Gd-145	7.E-05	7.E-05	-	2.E+06	3.E+06	-	St/St/
Gd-146	5.E-08	1.E-07	-	2.E+03	4.E+03	-	St/St/
Gd-147	2.E-06	2.E-06	-	6.E+04	5.E+04	-	St/St/
Gd-148	3.E-12	1.E-11	-	1.E-01	5.E-01	-	BS/BS/
Gd-149	9.E-07	1.E-06	-	3.E+04	4.E+04	-	St/St/
Gd-151	2.E-07	5.E-07	-	6.E+03	2.E+04	-	BS/St/
Gd-152	4.E-12	2.E-11	-	2.E-01	6.E-01	-	BS/BS/
Gd-153	6.E-08	3.E-07	-	2.E+03	9.E+03	-	BS/St/



Radionuclide	Inhaled Air-Lung Retention Class			Inhaled Air-Lung Retention Class			Stochastic or Organ ¹
	μCi/ml			Bq/m ³			
	D	W	Y	D	W	Y	(D/W/Y)
Gd-159	3.E-06	2.E-06	-	1.E+05	9.E+04	-	St/St/
Tb-147	-	1.E-05	-	-	5.E+05	-	/St/
Tb-149	-	3.E-07	-	-	1.E+04	-	/St/
Tb-150	-	9.E-06	-	-	3.E+05	-	/St/
Tb-151	-	4.E-06	-	-	1.E+05	-	/St/
Tb-153	-	3.E-06	-	-	1.E+05	-	/St/
Tb-154	-	2.E-06	-	-	7.E+04	-	/St/
Tb-155	-	3.E-06	-	-	1.E+05	-	/St/
Tb-156m (24 h)	-	3.E-06	-	-	1.E+05	-	/St/
Tb-156m (5 h)	-	1.E-05	-	-	4.E+05	-	/St/
Tb-156	-	6.E-07	-	-	2.E+04	-	/St/
Tb-157	-	1.E-07	-	-	5.E+03	-	/BS/
Tb-158	-	8.E-09	-	-	3.E+02	-	/St/
Tb-160	-	1.E-07	-	-	4.E+03	-	/St/
Tb-161	-	7.E-07	-	-	2.E+04	-	/St/
Dy-155	-	1.E-05	-	-	4.E+05	-	/St/
Dy-157	-	3.E-05	-	-	1.E+06	-	/St/
Dy-159	-	1.E-06	-	-	4.E+04	-	/St/
Dy-165	-	2.E-05	-	-	7.E+05	-	/St/
Dy-166	-	3.E-07	-	-	1.E+04	-	/St/
Ho-155	-	7.E-05	-	-	2.E+06	-	/St/
Ho-157	-	6.E-04	-	-	2.E+07	-	/St/
Ho-159	-	4.E-04	-	-	2.E+07	-	/St/
Ho-161	-	2.E-04	-	-	7.E+06	-	/St/
Ho-162m	-	1.E-04	-	-	4.E+06	-	/St/
Ho-162	-	1.E-03	-	-	4.E+07	-	/St/
Ho-164m	-	1.E-04	-	-	5.E+06	-	/St/
Ho-164	-	3.E-04	-	-	1.E+07	-	/St/



Radionuclide	Inhaled Air-Lung Retention Class			Inhaled Air-Lung Retention Class			Stochastic or Organ ¹
	μCi/ml			Bq/m ³			
	D	W	Y	D	W	Y	(D/W/Y)
Ho-166m	-	3.E-09	-	-	1.E+02	-	/St/
Ho-166	-	7.E-07	-	-	3.E+04	-	/St/
Ho-167	-	2.E-05	-	-	9.E+05	-	/St/
Er-161	-	3.E-05	-	-	1.E+06	-	/St/
Er-165	-	8.E-05	-	-	3.E+06	-	/St/
Er-169	-	1.E-06	-	-	4.E+04	-	/St/
Er-171	-	4.E-06	-	-	2.E+05	-	/St/
Er-172	-	6.E-07	-	-	2.E+04	-	/St/
Tm-162	-	1.E-04	-	-	4.E+06	-	/St/
Tm-166	-	6.E-06	-	-	2.E+05	-	/St/
Tm-167	-	8.E-07	-	-	3.E+04	-	/St/
Tm-170	-	9.E-08	-	-	3.E+03	-	/St/
Tm-171	-	1.E-07	-	-	5.E+03	-	/BS/
Tm-172	-	5.E-07	-	-	2.E+04	-	/St/
Tm-173	-	5.E-06	-	-	2.E+05	-	/St/
Tm-175	-	1.E-04	-	-	4.E+06	-	/St/
Yb-162	-	1.E-04	1.E-04	-	5.E+06	4.E+06	/St/St
Yb-166	-	8.E-07	8.E-07	-	3.E+04	3.E+04	/St/St
Yb-167	-	3.E-04	3.E-04	-	1.E+07	1.E+07	/St/St
Yb-169	-	3.E-07	3.E-07	-	1.E+04	1.E+04	/St/St
Yb-175	-	1.E-06	1.E-06	-	5.E+04	5.E+04	/St/St
Yb-177	-	2.E-05	2.E-05	-	8.E+05	7.E+05	/St/St
Yb-178	-	2.E-05	1.E-05	-	6.E+05	6.E+05	/St/St
Lu-169	-	2.E-06	2.E-06	-	7.E+04	7.E+04	/St/St
Lu-170	-	9.E-07	8.E-07	-	3.E+04	3.E+04	/St/St
Lu-171	-	8.E-07	8.E-07	-	3.E+04	3.E+04	/St/St
Lu-172	-	5.E-07	5.E-07	-	2.E+04	2.E+04	/St/St
Lu-173	-	1.E-07	1.E-07	-	4.E+03	4.E+03	/BS/St



Radionuclide	Inhaled Air-Lung Retention Class			Inhaled Air-Lung Retention Class			Stochastic or Organ ¹
	μCi/ml			Bq/m ³			
	D	W	Y	D	W	Y	(D/W/Y)
Lu-174m	-	1.E-07	9.E-08	-	4.E+03	3.E+03	/BS/St
Lu-174	-	5.E-08	7.E-08	-	2.E+03	2.E+03	/BS/St
Lu-176m	-	1.E-05	1.E-05	-	4.E+05	4.E+05	/St/St
Lu-176	-	2.E-09	3.E-09	-	7.E+01	1.E+02	/BS/St
Lu-177m	-	5.E-08	3.E-08	-	2.E+03	1.E+03	/BS/St
Lu-177	-	9.E-07	9.E-07	-	3.E+04	3.E+04	/St/St
Lu-178m	-	8.E-05	7.E-05	-	3.E+06	3.E+06	/St/St
Lu-178	-	5.E-05	5.E-05	-	2.E+06	2.E+06	/St/St
Lu-179	-	8.E-06	6.E-06	-	3.E+05	2.E+05	/St/St
Hf-170	2.E-06	2.E-06	-	9.E+04	7.E+04	-	St/St/
Hf-172	4.E-09	2.E-08	-	1.E+02	6.E+02	-	BS/BS/
Hf-173	5.E-06	5.E-06	-	2.E+05	2.E+05	-	St/St/
Hf-175	4.E-07	5.E-07	-	2.E+04	2.E+04	-	BS/St/
Hf-177m	2.E-05	4.E-05	-	9.E+05	1.E+06	-	St/St/
Hf-178m	6.E-10	2.E-09	-	2.E+01	8.E+01	-	BS/BS/
Hf-179m	1.E-07	3.E-07	-	5.E+03	9.E+03	-	BS/St/
Hf-180m	9.E-06	1.E-05	-	3.E+05	4.E+05	-	St/St/
Hf-181	7.E-08	2.E-07	-	3.E+03	7.E+03	-	BS/St/
Hf-182m	4.E-05	6.E-05	-	1.E+06	2.E+06	-	St/St/
Hf-182	3.E-10	1.E-09	-	1.E+01	5.E+01	-	BS/BS/
Hf-183	2.E-05	2.E-05	-	7.E+05	8.E+05	-	St/St/
Hf-184	3.E-06	3.E-06	-	1.E+05	1.E+05	-	St/St/
Ta-172	-	5.E-05	4.E-05	-	2.E+06	2.E+06	/St/St
Ta-173	-	8.E-06	7.E-06	-	3.E+05	3.E+05	/St/St
Ta-174	-	4.E-05	4.E-05	-	1.E+06	1.E+06	/St/St
Ta-175	-	7.E-06	6.E-06	-	3.E+05	2.E+05	/St/St
Ta-176	-	5.E-06	5.E-06	-	2.E+05	2.E+05	/St/St
Ta-177	-	8.E-06	7.E-06	-	3.E+05	3.E+05	/St/St



Radionuclide	Inhaled Air-Lung Retention Class			Inhaled Air-Lung Retention Class			Stochastic or Organ ¹
	µCi/ml			Bq/m ³			
	D	W	Y	D	W	Y	(D/W/Y)
Ta-178	-	4.E-05	3.E-05	-	1.E+06	1.E+06	/St/St
Ta-179	-	2.E-06	4.E-07	-	8.E+04	1.E+04	/St/St
Ta-180m	-	3.E-05	2.E-05	-	1.E+06	9.E+05	/St/St
Ta-180	-	2.E-07	1.E-08	-	7.E+03	4.E+02	/St/St
Ta-182m	-	2.E-04	2.E-04	-	8.E+06	6.E+06	/St/St
Ta-182	-	1.E-07	6.E-08	-	5.E+03	2.E+03	/St/St
Ta-183	-	5.E-07	4.E-07	-	2.E+04	2.E+04	/St/St
Ta-184	-	2.E-06	2.E-06	-	8.E+04	7.E+04	/St/St
Ta-185	-	3.E-05	3.E-05	-	1.E+06	1.E+06	/St/St
Ta-186	-	1.E-04	9.E-05	-	4.E+06	3.E06	/St/St
W-176	2.E-05	-	-	8.E+05	-	-	St/ /
W-177	4.E-05	-	-	1.E+06	-	-	St/ /
W-178	8.E-06	-	-	3.E+05	-	-	St/ /
W-179	7.E-04	-	-	3.E+07	-	-	St/ /
W-181	1.E-05	-	-	5.E+05	-	-	St/ /
W-185	3.E-06	-	-	1.E+05	-	-	St/ /
W-187	4.E-06	-	-	2.E+05	-	-	St/ /
W-188	5.E-07	-	-	2.E+04	-	-	St/ /
Re-177	1.E-04	2.E-04	-	4.E+06	5.E+06	-	St/St/
Re-178	1.E-04	1.E-04	-	4.E+06	4.E+06	-	St/St/
Re-181	4.E-06	4.E-06	-	1.E+05	1.E+05	-	St/St/
Re-182 (64 h)	1.E-06	9.E-07	-	4.E+04	3.E+04	-	St/St/
Re-182 (12 h)	5.E-06	6.E-06	-	2.E+05	2.E+05	-	St/St/
Re-184m	1.E-06	2.E-07	-	5.E+04	7.E+03	-	St/St/
Re-184	2.E-06	6.E-07	-	6.E+04	2.E+04	-	St/St/
Re-186m	7.E-7	6.E-08	-	3.E+04	2.E+03	-	SW/St/
Re-186	1.E-06	7.E-07	-	5.E+04	3.E+04	-	St/St/
Re-187	3.E-04	4.E-05	-	1.E+07	2.E+06	-	SW/St/



Radionuclide	Inhaled Air-Lung Retention Class			Inhaled Air-Lung Retention Class			Stochastic or Organ ¹
	μCi/ml			Bq/m ³			
	D	W	Y	D	W	Y	(D/W/Y)
Re-188m	6.E-05	6.E-05	-	2.E+06	2.E+06	-	St/St/
Re-188	1.E-06	1.E-06	-	4.E+04	4.E+04	-	St/St/
Re-189	2.E-06	2.E-06	-	8.E+04	7.E+04	-	St/St/
Os-180	2.E-04	2.E-04	2.E-04	6.E+06	8.E+06	7.E+06	St/St/St
Os-181	2.E-05	2.E-05	2.E-05	7.E+05	7.E+05	7.E+05	St/St/St
Os-182	2.E-06	2.E-06	2.E-06	9.E+04	7.E+04	6.E+04	St/St/St
Os-185	2.E-07	3.E-07	3.E-07	8.E+03	1.E+04	1.E+04	St/St/St
Os-189m	1.E-04	9.E-05	7.E-05	4.E+06	3.E+06	3.E+06	St/St/St
Os-191m	1.E-05	9.E-06	7.E-06	4.E+05	3.E+05	3.E+05	St/St/St
Os-191	9.E-07	7.E-07	6.E-07	3.E+04	3.E+04	2.E+04	St/St/St
Os-193	2.E-06	1.E-06	1.E-06	7.E+04	5.E+04	4.E+04	St/St/St
Os-194	2.E-08	2.E-08	3.E-09	7.E+02	9.E+02	1.E+02	St/St/St
Ir-182	6.E-05	6.E-05	5.E-05	2.E+06	2.E+06	2.E+06	St/St/St
Ir-184	1.E-05	1.E-05	1.E-05	4.E+05	5.E+05	4.E+05	St/St/St
Ir-185	5.E-06	5.E-06	4.E-06	2.E+05	2.E+05	2.E+05	St/St/St
Ir-186	3.E-06	3.E-06	2.E-06	1.E+05	1.E+05	9.E+04	St/St/St
Ir-187	1.E-05	1.E-05	1.E-05	5.E+05	5.E+05	4.E+05	St/St/St
Ir-188	2.E-06	2.E-06	1.E-06	7.E+04	6.E+04	5.E+04	St/St/St
Ir-189	2.E-06	2.E-06	2.E-06	7.E+04	6.E+04	6.E+04	St/St/St
Ir-190m	8.E-05	9.E-05	8.E-05	3.E+06	3.E+06	3.E+06	St/St/St
Ir-190	4.E-07	4.E-07	4.E-07	1.E+04	2.E+04	1.E+04	St/St/St
Ir-192m	4.E-08	9.E-08	6.E-09	1.E+03	3.E+03	2.E+02	St/St/St
Ir-192	1.E-07	2.E-07	9.E-08	4.E+03	6.E+03	3.E+03	St/St/St
Ir-194m	4.E-08	7.E-08	4.E-08	2.E+03	3.E+03	2.E+03	St/St/St
Ir-194	1.E-06	8.E-07	8.E-07	5.E+04	3.E+04	3.E+04	St/St/St
Ir-195m	1.E-05	1.E-05	9.E-06	4.E+05	4.E+05	3.E+05	St/St/St
Ir-195	2.E-05	2.E-05	2.E-05	6.E+05	8.E+05	7.E+05	St/St/St
Pt-186	2.E-05	-	-	6.E+05	-	-	St/ /



Radionuclide	Inhaled Air-Lung Retention Class			Inhaled Air-Lung Retention Class			Stochastic or Organ ¹
	μCi/ml			Bq/m ³			
	D	W	Y	D	W	Y	(D/W/Y)
Pt-188	7.E-07	-	-	3.E+04	-	-	St/ /
Pt-189	1.E-05	-	-	4.E+05	-	-	St/ /
Pt-191	3.E-06	-	-	1.E+05	-	-	St/ /
Pt-193m	2.E-06	-	-	9.E+04	-	-	St/ /
Pt-193	1.E-05	-	-	4.E+05	-	-	St/ /
Pt-195m	2.E-06	-	-	7.E+04	-	-	St/ /
Pt-197m	2.E-05	-	-	7.E+05	-	-	St/ /
Pt-197	4.E-06	-	-	2.E+05	-	-	St/ /
Pt-199	6.E-05	-	-	2.E+06	-	-	St/ /
Pt-200	1.E-06	-	-	5.E+04	-	-	St/ /
Au-193	1.E-05	8.E-06	8.E-06	4.E+05	3.E+05	3.E+05	St/St/St
Au-194	3.E-06	2.E-06	2.E-06	1.E+05	9.E+04	8.E+04	St/St/St
Au-195	5.E-06	6.E-07	2.E-07	2.E+05	2.E+04	6.E+03	St/St/St
Au-198m	1.E-06	5.E-07	5.E-07	4.E+04	2.E+04	2.E+04	St/St/St
Au-198	2.E-06	7.E-07	7.E-07	6.E+04	3.E+04	3.E+04	St/St/St
Au-199	4.E-06	2.E-06	2.E-06	1.E+05	6.E+04	6.E+04	St/St/St
Au-200m	1.E-06	1.E-06	1.E-06	5.E+04	4.E+04	4.E+04	St/St/St
Au-200	3.E-05	3.E-05	3.E-05	1.E+06	1.E+06	1.E+06	St/St/St
Au-201	9.E-05	1.E-04	9.E-05	3.E+06	4.E+06	4.E+06	St/St/St
Hg-193m (Org)	6.E-06	-	-	2.E+05	-	-	St/ /
Hg-193m (Inorg)	4.E-06	3.E-06	-	1.E+05	1.E+05	-	St/St/
Hg-193m (Vapor)	-	4.E-06	-	-	1.E+05	-	/St/
Hg-193 (Org)	3.E-05	-	-	1.E+06	-	-	St/ /
Hg-193 (Inorg)	2.E-05	2.E-05	-	7.E+05	6.E+05	-	St/St/
Hg-193 (Vapor)	-	1.E-05	-	-	5.E+05	-	/St/
Hg-194 (Org)	1.E-08	-	-	4.E+02	-	-	St/ /
Hg-194 (Inorg)	2.E-08	5.E-08	-	7.E+02	2.E+03	-	St/St/
Hg-194 (Vapor)	-	1.E-08	-	-	5.E+02	-	/St/



Radionuclide	Inhaled Air-Lung Retention Class			Inhaled Air-Lung Retention Class			Stochastic or Organ ¹
	μCi/ml			Bq/m ³			
	D	W	Y	D	W	Y	(D/W/Y)
Hg-195m (Org)	3.E-06	-	-	9.E+04	-	-	St/ /
Hg-195m (Inorg)	2.E-06	2.E-06	-	8.E+04	6.E+04	-	St/St/
Hg-195m (Vapor)	-	2.E-06	-	-	6.E+04	-	/St/
Hg-195 (Org)	2.E-05	-	-	7.E+05	-	-	St/ /
Hg-195 (Inorg)	1.E-05	1.E-05	-	5.E+05	5.E+05	-	St/St/
Hg-195 (Vapor)	-	1.E-05	-	-	5.E+05	-	/St/
Hg-197m (Org)	4.E-06	-	-	1.E+05	-	-	St/ /
Hg-197m (Inorg)	3.E-06	2.E-06	-	1.E+05	8.E+04	-	St/St/
Hg-197m (Vapor)	-	2.E-06	-	-	8.E+04	-	/St/
Hg-197 (Org)	6.E-06	-	-	2.E+05	-	-	St/ /
Hg-197 (Inorg)	5.E-06	4.E-06	-	2.E+05	1.E+05	-	St/St/
Hg-197 (Vapor)	-	3.E-05	-	-	1.E+05	-	/St/
Hg-199m (Org)	7.E-05	-	-	3.E+06	-	-	St/ /
Hg-199m (Inorg)	6.E-05	7.E-05	-	2.E+06	3.E+06	-	St/St/
Hg-199m (Vapor)	-	3.E-05	-	-	1.E+06	-	/St/
Hg-203 (Org)	3.E-07	-	-	1.E+04	-	-	St/ /
Hg-203 (Inorg)	5.E-07	5.E-07	-	2.E+04	2.E+04	-	St/St/
Hg-203 (Vapor)	-	3.E-07	-	-	1.E+04	-	/St/
Tl-194m	6.E-05	-	-	2.E+06	-	-	St/ /
Tl-194	3.E-04	-	-	9.E+06	-	-	St/ /
Tl-195	5.E-05	-	-	2.E+06	-	-	St/ /
Tl-197	5.E-05	-	-	2.E+06	-	-	St/ /
Tl-198m	2.E-05	-	-	9.E+05	-	-	St/ /
Tl-198	1.E-05	-	-	5.E+05	-	-	St/ /
Tl-199	3.E-05	-	-	1.E+06	-	-	St/ /
Tl-200	5.E-06	-	-	2.E+05	-	-	St/ /
Tl-201	9.E-06	-	-	3.E+05	-	-	St/ /
Tl-202	2.E-06	-	-	8.E+04	-	-	St/ /



Radionuclide	Inhaled Air-Lung Retention Class			Inhaled Air-Lung Retention Class			Stochastic or Organ ¹
	μCi/ml			Bq/m ³			
	D	W	Y	D	W	Y	(D/W/Y)
Tl-204	9.E-07	-	-	3.E+04	-	-	St/ /
Pb-195m	8.E-05	-	-	3.E+06	-	-	St/ /
Pb-198	3.E-05	-	-	1.E+06	-	-	St/ /
Pb-199	3.E-05	-	-	1.E+06	-	-	St/ /
Pb-200	3.E-06	-	-	1.E+05	-	-	St/ /
Pb-201	9.E-06	-	-	3.E+05	-	-	St/ /
Pb-202m	1.E-05	-	-	4.E+05	-	-	St/ /
Pb-202	2.E-08	-	-	8.E+02	-	-	St/ /
Pb-203	4.E-06	-	-	2.E+05	-	-	St/ /
Pb-205	6.E-07	-	-	2.E+04	-	-	St/ /
Pb-209	2.E-05	-	-	9.E+05	-	-	St/ /
Pb-210	1.E-10	-	-	4.E+00	-	-	BS/ /
Pb-211	3.E-07	-	-	1.E+04	-	-	St/ /
Pb-212	1.E-08	-	-	5.E+02	-	-	St/ /
Pb-214	3.E-07	-	-	1.E+04	-	-	St/ /
Bi-200	3.E-05	4.E-05	-	1.E+06	2.E+06	-	St/St/
Bi-201	1.E-05	2.E-05	-	4.E+05	6.E+05	-	St/St/
Bi-202	2.E-05	3.E-05	-	6.E+05	1.E+06	-	St/St/
Bi-203	3.E-06	2.E-06	-	1.E+05	9.E+04	-	St/St/
Bi-205	1.E-06	5.E-07	-	4.E+04	2.E+04	-	St/St/
Bi-206	6.E-07	4.E-07	-	2.E+04	1.E+04	-	St/St/
Bi-207	7.E-07	2.E-07	-	3.E+04	5.E+03	-	St/St/
Bi-210m	2.E-09	3.E-10	-	7.E+01	1.E+01	-	K/St/
Bi-210	1.E-07	1.E-08	-	4.E+03	4.E+02	-	K/St/
Bi-212	1.E-07	1.E-07	-	4.E+03	4.E+03	-	St/St/
Bi-213	1.E-07	2.E-07	-	5.E+03	5.E+03	-	St/St/
Bi-214	3.E-07	4.E-07	-	1.E+04	1.E+04	-	St/St/



Radionuclide	Inhaled Air-Lung Retention Class			Inhaled Air-Lung Retention Class			Stochastic or Organ ¹
	μCi/ml			Bq/m ³			
	D	W	Y	D	W	Y	(D/W/Y)
Po-203	3.E-05	4.E-05	-	1.E+06	1.E+06	-	St/St/
Po-205	2.E-05	3.E-05	-	6.E+05	1.E+06	-	St/St/
Po-207	1.E-05	1.E-05	-	4.E+05	4.E+05	-	St/St/
Po-210	3.E-10	3.E-10	-	1.E+01	1.E+01	-	E/St/
At-207	1.E-06	9.E-07	-	4.E+04	3.E+04	-	St/St/
At-211	3.E-08	2.E-08	-	1.E+03	8.E+02	-	St/St/
Rn-220	8.E-09 ⁴	- ⁴	- ⁴	3.E+02 ⁴	- ⁴	- ⁴	- ⁴
Rn-222	3.E-08 ⁴	- ⁴	- ⁴	1.E+03 ⁴	- ⁴	- ⁴	- ⁴
Fr-222	2.E-07	-	-	7.E+03	-	-	St/ /
Fr-223	3.E-07	-	-	1.E+04	-	-	St/ /
Ra-223	-	3.E-10	-	-	1.E+01	-	/St/
Ra-224	-	7.E-10	-	-	3.E+01	-	/St/
Ra-225	-	3.E-10	-	-	1.E+01	-	/St/
Ra-226	-	3.E-10	-	-	1.E+01	-	/St/
Ra-227	-	6.E-06	-	-	2.E+05	-	/BS/
Ra-228	-	5.E-10	-	-	2.E+01	-	/St/
Ac-224	1.E-08	2.E-08	2.E-08	4.E+02	8.E+02	7.E+02	BS/St/St
Ac-225	1.E-10	3.E-10	3.E-10	4.E+00	1.E+01	1.E+01	BS/St/St
Ac-226	1.E-09	2.E-09	2.E-09	5.E+01	8.E+01	7.E+01	BS/St/St
Ac-227	2.E-13	7.E-13	2.E-12	7.E-03	3.E-02	6.E-02	BS/BS/St
Ac-228	4.E-09	2.E-08	2.E-08	2.E+02	6.E+02	7.E+02	BS/BS/St
Th-226	-	7.E-08	6.E-08	-	2.E+03	2.E+03	/St/St
Th-227	-	1.E-10	1.E-10	-	5.E+00	5.E+00	/St/St
Th-228	-	4.E-12	7.E-12	-	2.E-01	3.E-01	/BS/St
Th-229	-	4.E-13	1.E-12	-	1.E-02	4.E-02	/BS/BS
Th-230	-	3.E-12	7.E-12	-	9.E-02	2.E-01	/BS/BS
Th-231	-	3.E-06	3.E-06	-	1.E+05	1.E+05	/St/St
Th-232	-	5.E-13	1.E-12	-	2.E-02	4.E-02	/BS/BS



Radionuclide	Inhaled Air-Lung Retention Class			Inhaled Air-Lung Retention Class			Stochastic or Organ ¹
	μCi/ml			Bq/m ³			
	D	W	Y	D	W	Y	(D/W/Y)
Th-234	-	9.E-08	6.E-08	-	3.E+03	2.E+03	/St/St
Pa-227	-	5.E-08	4.E-08	-	2.E+03	2.E+03	/St/St
Pa-228	-	5.E-09	5.E-09	-	2.E+02	2.E+02	/BS/St
Pa-230	-	2.E-09	1.E-09	-	7.E+01	5.E+01	/St/St
Pa-231	-	7.E-13	2.E-12	-	2.E-02	6.E-02	/BS/BS
Pa-232	-	9.E-09	2.E-08	-	3.E+02	9.E+02	/BS/BS
Pa-233	-	3.E-07	2.E-07	-	1.E+04	9.E+03	/St/St
Pa-234	-	3.E-06	3.E-06	-	1.E+05	1.E+05	/St/St
U-230	2.E-10	1.E-10	1.E-10	6.E+00	5.E+00	4.E+00	BS/St/St
U-231	3.E-06	2.E-06	2.E-06	1.E+05	9.E+04	7.E+04	St/St/St
U-232	9.E-11	2.E-10	3.E-12	3.E+00	6.E+00	1.E-01	BS/St/St
U-233	5.E-10	3.E-10	2.E-11	2.E+01	1.E+01	6.E-01	BS/St/St
U-234	5.E-10	3.E-10	2.E-11	2.E+01	1.E+01	6.E-01	BS/St/St
U-235	6.E-10	3.E-10	2.E-11	2.E+01	1.E+01	6.E-01	BS/St/St
U-236	6.E-10	3.E-10	2.E-11	2.E+01	1.E+01	6.E-01	BS/St/St
U-237	1.E-06	7.E-07	6.E-07	4.E+04	3.E+04	2.E+04	St/St/St
U-238	6.E-10	3.E-10	2.E-11	2.E+01	1.E+01	6.E-01	BS/St/St
U-239	8.E-05	7.E-05	6.E-05	3.E+06	3.E+06	2.E+06	St/St/St
U-240	2.E-06	1.E-06	1.E-06	6.E+04	4.E+04	4.E+04	St/St/St
Np-232	-	1.E-06 ⁵	-	-	4.E+04 ⁵	-	/BS/
Np-233	-	1.E-03 ⁵	-	-	5.E+07 ⁵	-	/St/
Np-234	-	1.E-06 ⁵	-	-	4.E+04 ⁵	-	/St/
Np-235	-	5.E-07 ⁵	-	-	2.E+04 ⁵	-	/BS/
Np-236 (1.E+05 yr)	-	1.E-11 ⁵	-	-	4.E-01 ⁵	-	/BS/
Np-236 (22 h)	-	2.E-08 ⁵	-	-	6.E+02 ⁵	-	/BS/
Np-237	-	2.E-12 ⁵	-	-	9.E-02 ⁵	-	/BS/
Np-238	-	4.E-08 ⁵	-	-	1.E+03 ⁵	-	/BS/



Radionuclide	Inhaled Air-Lung Retention Class			Inhaled Air-Lung Retention Class			Stochastic or Organ ¹
	μCi/ml			Bq/m ³			
	D	W	Y	D	W	Y	(D/W/Y)
Np-239	-	1.E-06 ⁵	-	-	4.E+04 ⁵	-	/St/
Np-240	-	3.E-05 ⁵	-	-	1.E+06 ⁵	-	/St/
Pu-234	-	9.E-08 ⁵	8.E-08 ⁵	-	3.E+03 ⁵	3.E+03 ⁵	/St/St
Pu-235	-	1.E-03 ⁵	1.E-03 ⁵	-	5.E+07 ⁵	4.E+07 ⁵	/St/St
Pu-236	-	7.E-12 ⁵	1.E-11 ⁵	-	3.E-01 ⁵	6.E-01 ⁵	/BS/St
Pu-237	-	1.E-06 ⁵	1.E-06 ⁵	-	5.E+04 ⁵	5.E+04 ⁵	/St/St
Pu-238	-	3.E-12 ⁵	7.E-12 ⁵	-	9.E-02 ⁵	3.E-01 ⁵	/BS/BS
Pu-239	-	2.E-12 ⁵	6.E-12 ⁵	-	8.E-02 ⁵	2.E-01 ⁵	/BS/BS
Pu-240	-	2.E-12 ⁵	6.E-12 ⁵	-	8.E-02 ⁵	2.E-01 ⁵	/BS/BS
Pu-241	-	1.E-10 ⁵	3.E-10 ⁵	-	4.E+00 ⁵	1.E+01 ⁵	/BS/BS
Pu-242	-	2.E-12 ⁵	6.E-12 ⁵	-	9.E-02 ⁵	2.E-01 ⁵	/BS/BS
Pu-243	-	1.E-05 ⁵	1.E-05 ⁵	-	5.E+05 ⁵	6.E+05 ⁵	/St/St
Pu-244	-	2.E-12 ⁵	6.E-12 ⁵	-	9.E-02 ⁵	2.E-01 ⁵	/BS/BS
Pu-245	-	2.E-06 ⁵	2.E-06 ⁵	-	7.E+04 ⁵	6.E+04 ⁵	/St/St
Am-237	-	1.E-04 ⁵	-	-	4.E+06 ⁵	-	/St/
Am-238	-	1.E-06 ⁵	-	-	4.E+04 ⁵	-	/BS/
Am-239	-	5.E-06 ⁵	-	-	2.E+05 ⁵	-	/St/
Am-240	-	1.E-06 ⁵	-	-	4.E+04 ⁵	-	/St/
Am-241	-	2.E-12 ⁵	-	-	8.E-02 ⁵	-	/BS/
Am-242m	-	2.E-12 ⁵	-	-	8.E-02 ⁵	-	/BS/
Am-242	-	3.E-08 ⁵	-	-	1.E+03 ⁵	-	/BS/
Am-243	-	2.E-12 ⁵	-	-	8.E-02 ⁵	-	/BS/
Am-244m	-	2.E-06 ⁵	-	-	6.E+04 ⁵	-	/BS/
Am-244	-	7.E-08 ⁵	-	-	3.E-03 ⁵	-	/BS/
Am-245	-	3.E-05 ⁵	-	-	1.E+06 ⁵	-	/St/
Am-246m	-	7.E-05 ⁵	-	-	3.E+06 ⁵	-	/St/
Am-246	-	4.E-05 ⁵	-	-	2.E+06 ⁵	-	/St/
Cm-238	-	4.E-07 ⁵	-	-	2.E+04 ⁵	-	/St/



Radionuclide	Inhaled Air-Lung Retention Class			Inhaled Air-Lung Retention Class			Stochastic or Organ ¹
	µCi/ml			Bq/m ³			
	D	W	Y	D	W	Y	(D/W/Y)
Cm-240	-	2.E-10 ⁵	-	-	8.E+00 ⁵	-	/BS/
Cm-241	-	9.E-09 ⁵	-	-	4.E+02 ⁵	-	/BS/
Cm-242	-	1.E-10 ⁵	-	-	4.E+00 ⁵	-	/BS/
Cm-243	-	3.E-12 ⁵	-	-	1.E-01 ⁵	-	/BS/
Cm-244	-	4.E-12 ⁵	-	-	2.E-01 ⁵	-	/BS/
Cm-245	-	2.E-12 ⁵	-	-	8.E-02 ⁵	-	/BS/
Cm-246	-	2.E-12 ⁵	-	-	8.E-02 ⁵	-	/BS/
Cm-247	-	2.E-12 ⁵	-	-	9.E-02 ⁵	-	/BS/
Cm-248	-	6.E-13 ⁵	-	-	2.E-02 ⁵	-	/BS/
Cm-249	-	6.E-06 ⁵	-	-	2.E+05 ⁵	-	/BS/
Bk-245	-	5.E-07	-	-	2.E+04	-	/St/
Bk-246	-	1.E-06	-	-	5.E+04	-	/St/
Bk-247	-	2.E-12	-	-	8.E-02	-	/BS/
Bk-249	-	9.E-10	-	-	3.E+01	-	/BS/
Bk-250	-	2.E-07	-	-	7.E+03	-	/BS/
Cf-244	-	2.E-07 ⁵	2.E-07 ⁵	-	9.E+03 ⁵	9.E+03 ⁵	/St/St
Cf-246	-	4.E-09 ⁵	4.E-09 ⁵	-	2.E+02 ⁵	1.E+02 ⁵	/St/St
Cf-248	-	4.E-11 ⁵	5.E-11 ⁵	-	1.E+00 ⁵	2.E+00 ⁵	/BS/St
Cf-249	-	2.E-12 ⁵	6.E-12 ⁵	-	8.E-02 ⁵	2.E-01 ⁵	/BS/BS
Cf-250	-	5.E-12 ⁵	1.E-11 ⁵	-	2.E-01 ⁵	4.E-01 ⁵	/BS/St
Cf-251	-	2.E-12 ⁵	5.E-12 ⁵	-	8.E-02 ⁵	2.E-01 ⁵	/BS/BS
Cf-252	-	1.E-11 ⁵	2.E-11 ⁵	-	4.E-01 ⁵	6.E-01 ⁵	/BS/St
Cf-253	-	8.E-10 ⁵	7.E-10 ⁵	-	3.E+01 ⁵	3.E+01 ⁵	/St/St
Cf-254	-	9.E-12 ⁵	7.E-12 ⁵	-	3.E-01 ⁵	3.E-01 ⁵	/St/St
Es-250	-	3.E-07	-	-	1.E+04	-	/BS/
Es-251	-	4.E-07	-	-	2.E+04	-	/BS/
Es-253	-	6.E-10	-	-	2.E+01	-	/St/
Es-254m	-	4.E-09	-	-	2.E+02	-	/St/



Radionuclide	Inhaled Air-Lung Retention Class			Inhaled Air-Lung Retention Class			Stochastic or Organ ¹
	μCi/ml			Bq/m ³			
	D	W	Y	D	W	Y	(D/W/Y)
Es-254	-	4.E-11	-	-	2.E+00	-	/BS/
Fm-252	-	6.E-09	-	-	2.E+02	-	/St/
Fm-253	-	4.E-09	-	-	2.E+02	-	/St/
Fm-254	-	4.E-08	-	-	2.E+03	-	/St/
Fm-255	-	9.E-09	-	-	3.E+02	-	/St/
Fm-257	-	1.E-10	-	-	4.E+00	-	/E/
Md-257	-	4.E-08	-	-	2.E+03	-	/St/
Md-258	-	1.E-10	-	-	4.E+00	-	/BS/

Footnotes for Appendix 2D

1. A determination of whether the DACs are controlled by stochastic (St) or nonstochastic (organ) dose, or if they both give the same result (E), for each lung retention class, is given in this column. The key to the organ notation for nonstochastic dose is: BS = Bone surface, K = Kidney, L = Liver, SW = Stomach wall, and T = Thyroid. A blank indicates that no calculations were performed for the lung retention class shown.
 2. The ICRP identifies tritiated water and carbon as having immediate uptake and distribution; therefore no solubility classes are designated. For the purposes of this table, the DAC values are shown as being constant, independent of solubility class. For tritiated water, the inhalation DAC values allow for an additional 50% absorption through the skin, as described in ICRP Publication No. 30: Limits for Intakes of Radionuclides by Workers. For elemental tritium, the DAC values are based solely on consideration of the dose-equivalent rate to the tissues of the lung from inhaled tritium gas contained within the lung, without absorption in the tissues.
 3. A dash indicates no values given for this data category.
 4. These values are appropriate for protection from radon combined with its short-lived daughters and are based on information given in ICRP Publication 32: Limits for Inhalation of Radon Daughters by Workers and Federal Guidance Report No. 11: Limiting Values of Radionuclide Intake and Air Concentrations, and Dose Conversion Factors for Inhalation, Submersion, and Ingestion (EPA 520/1-88-020). The values given are for 100% equilibrium concentration conditions of the radon daughters with the parent. To allow for an actual measured equilibrium concentration or a demonstrated equilibrium concentration, the values given in this table should be multiplied by the ratio (100%/actual%) or (100%/demonstrated%), respectively. Alternatively, the DAC values for Rn-220 and Rn-222 may be replaced by 1 WL* and 1/3 WL*, respectively, for appropriate limiting of daughter concentrations. Because of the dosimetric considerations for radon, no f₁ or lung clearance values are listed.
- * A "Working Level" (WL) is any combination of short-lived radon daughters, in one liter of air without regard to the degree of equilibrium, that will result in the ultimate emission of 1.3 E+05 MeV of alpha energy.

Appendix 2E: Derived Air Concentration (DAC) For Workers From External Exposure During Immersion In A Contaminated Atmospheric Cloud

- a. The data presented in Appendix 2E are to be used for controlling occupational exposures in accordance with § 835.209, identifying the need for air monitoring in accordance with § 835.403 and identifying the need for posting of airborne radioactivity areas in accordance with § 835.603(d).
- b. The air immersion DAC values shown in this appendix are based on a stochastic dose limit of 5 rem (0.05 Sv) per year or a nonstochastic (organ) dose limit of 50 rem (0.5 Sv) per year. Four columns of information are presented: (1) radionuclide; (2) half-life in units of seconds (s), minutes (min), hours (h), days (d), or years (yr); (3) air immersion DAC in units of $\mu\text{Ci}/\text{ml}$; and (4) air immersion DAC in units of Bq/m^3 . The data are listed by radionuclide in order of increasing atomic mass. The air immersion DACs were calculated for a continuous, unshielded exposure via immersion in a semi-infinite atmospheric cloud. The DACs listed in this appendix may be modified to allow for submersion in a cloud of finite dimensions.
- c. The DAC value for air immersion listed for a given radionuclide is determined either by a yearly limit on effective dose equivalent, which provides a limit on stochastic radiation effects, or by a limit on yearly dose equivalent to any organ, which provides a limit on nonstochastic radiation effects. For most of the radionuclides listed, the DAC value is determined by the yearly limit on effective dose equivalent. Thus, the few cases where the DAC value is determined by the yearly limit on shallow dose equivalent to the skin are indicated in the table by an appropriate footnote. Again, the DACs listed in this appendix account only for immersion in a semi-infinite cloud and do not account for inhalation or ingestion exposures.
- d. Three classes of radionuclides are included in the air immersion DACs as described below.
 - (1) Class 1. The first class of radionuclides includes selected noble gases and short-lived activation products that occur in gaseous form. For these radionuclides, inhalation doses are negligible compared to the external dose from immersion in an atmospheric cloud.
 - (2) Class 2. The second class of radionuclides includes those for which a DAC value for inhalation has been calculated, but for which the DAC value for external exposure to a contaminated atmospheric cloud is more restrictive (i.e., results in a lower DAC value). These radionuclides generally have half-lives of a few hours or less, or are eliminated from the body following inhalation sufficiently rapidly to limit the inhalation dose.
 - (3) Class 3. The third class of radionuclides includes selected isotopes with relatively short half-lives. These radionuclides typically have half-lives that are less than 10 minutes, they do not occur as a decay product of a longer lived radionuclide, or they lack sufficient decay data to permit internal dose calculations. These radionuclides are also typified by a radioactive emission of highly intense, high-energy photons and rapid removal from the body following inhalation.



- e. The DAC values are given for individual radionuclides. For known mixtures of radionuclides, determine the sum of the ratio of the observed concentration of a particular radionuclide and its corresponding DAC for all radionuclides in the mixture. If this sum exceeds unity (1), then the DAC has been exceeded. For unknown radionuclides, the most restrictive DAC (lowest value) for those isotopes not known to be absent shall be used.

Air Immersion DAC			
Radionuclide	Half-Life	($\mu\text{Ci/ml}$)	(Bq/m^3)
C-11	20.48 min	4.E-06	1.E+05
N-13	9.97 min	4.E-06	1.E+05
N-16	7.13 s	7.E-07	3.E+04
O-15	122.24 s	4.E-06	1.E+05
F-18 ¹	109.74 min	4.E-06	1.E+05
Na-24 ¹	15.00 h	9.E-07	3.E+04
Mg-27 ²	9.458 min	5.E-06	2.E+05
Al-28 ²	2.240 min	2.E-06	7.E+04
Cl-38 ¹	37.21 min	3.E-06	1.E+05
Ar-37	35.02 d	3.E-00	1.E+11
Ar-39	269 yr	2.E-04 ³	7.E+06 ³
Ar-41	1.827 h	3.E-06	1.E+05
K-43 ¹	22.6 h	5.E-06	2.E+05
Ca-49 ²	8.719 min	1.E-06	4.E+04
Sc-44 ¹	3.927 h	2.E-06	7.E+04
Sc-46m ²	18.72 s	5.E-05	2.E+06
Ti-45 ¹	3.08 h	5.E-06	2.E+05
Ti-51 ²	5.752 min	1.E-05	4.E+05
V-52 ²	3.75 min	3.E-06	1.E+05
Cr-49 ¹	42.09 min	5.E-06	2.E+05
Mn-52m ¹	21.4 min	2.E-06	7.E+04
Mn-56 ¹	2.5785 h	2.E-06	7.E+04
Mn-57 ²	1.47 min	6.E-05	2.E+06
Co-60m ¹	10.47 min	1.E-03	4.E+07
Ni-57 ^{1, 4}	36.08 h	2.E-06	7.E+04
Ni-65 ^{1, 5}	2.520 h	8.E-06	3.E+05



Air Immersion DAC			
Radionuclide	Half-Life	($\mu\text{Ci/ml}$)	(Bq/m^3)
Cu-61 ¹	3.408 h	5.E-06	2.E+05
Cu-62 ²	9.74 min	5.E-06	2.E+05
Ga-66 ¹	9.40 h	2.E-06	7.E+04
Ga-68 ¹	68.0 min	5.E-06	2.E+05
Ga-72 ¹	14.1 h	1.E-06	4.E+04
Se-73 ¹	7.15 h	4.E-06	1.E+05
Br-77 ¹	57.04 h	1.E-05 ⁶	4.E+05 ⁶
Br-80 ¹	17.4 min	5.E-05	2.E+06
Br-82 ¹	35.30 h	1.E-06	4.E+04
Br-84 ¹	31.80 min	2.E-06	7.E+04
Br-85 ²	172 s	5.E-05	2.E+06
Kr-79	35.04 h	2.E-05	7.E+05
Kr-81	2.1E+05 yr	5.E-04	2.E+07
Kr-83m	1.83 h	5.E-02	2.E+09
Kr-85	10.72 yr	1.E-04 ³	4.E+06 ³
Kr-85m	4.48 h	3.E-05	1.E+06
Kr-87	76.3 min	5.E-06	2.E+05
Kr-88	2.84 h	2.E-06	7.E+04
Kr-89	3.16 min	2.E-06	7.E+04
Kr-90	32.32 s	3.E-06	1.E+05
Rb-81 ¹	4.58 h	8.E-06	3.E+05
Rb-82 ²	1.25 min	2.E-06	7.E+04
Rb-88 ¹	17.8 min	7.E-06	3.E+05
Rb-89 ¹	15.44 min	2.E-06	7.E+04
Rb-90 ²	157 s	2.E-06	7.E+04
Rb-90m ²	258 s	1.E-06	4.E+04
Sr-85m ¹	67.66 min	2.E-05	7.E+04
Sr-87m ¹	2.805 h	6.E-05	2.E+06
Sr-92 ¹	2.71 h	3.E-06	1.E+05
Sr-93 ²	7.3 min	2.E-06	7.E+04



Air Immersion DAC			
Radionuclide	Half-Life	($\mu\text{Ci/ml}$)	(Bq/m^3)
Y-86 ¹	14.74 h	1.E-06	4.E+04
Y-90m ¹	3.19 h	5.E-06 ⁶	2.E+05 ⁶
Y-91m ¹	49.71 min	9.E-06	3.E+05
Nb-90 ¹	14.60 h	1.E-07	4.E+03
Nb-94m ²	6.26 min	9.E-04	3.E+07
Nb-97 ¹	72.1 min	7.E-06	3.E+05
Nb-97m ¹	60 s	6.E-06	2.E+05
Mo-91 ²	15.9 min	4.E-06	1.E+05
Mo-101 ¹	14.61 min	3.E-06	1.E+05
Tc-95 ¹	20.0 h	5.E-06	2.E+05
Tc-96m ¹	51.5 min	1.E-04	4.E+06
Tc-99m ¹	6.02 h	3.E-05	1.E+06
Tc-101 ¹	14.2 min	1.E-05	4.E+05
Ru-105 ¹	4.44 h	5.E-06	2.E+05
Rh-105m ²	45 s	1.E-04	4.E+06
Rh-106 ²	29.92 s	2.E-05	7.E+05
Ag-108 ²	2.37 min	2.E-04	7.E+06
Ag-109m ²	39.6 s	1.E-03	4.E+07
Ag-110 ²	24.57 s	9.E-05	3.E+06
Cd-111m ²	48.7 min	1.E-05	4.E+05
Cd-117 ¹	2.49 h	4.E-06	1.E+05
Cd-117m ¹	3.36 h	2.E-06	7.E+04
In-113m ¹	1.658 h	2.E-05	7.E+05
In-114 ²	71.9 s	1.E-04	4.E+06
In-116m ¹	54.15 min	2.E-06	7.E+04
In-117 ¹	43.8 min	7.E-06	3.E+05
Sb-117 ¹	2.80 h	3.E-05	1.E+06
Sb-126m ¹	19.0 min	3.E-06	1.E+05
Sb-129 ¹	4.40 h	3.E-06	1.E+05



Air Immersion DAC			
Radionuclide	Half-Life	($\mu\text{Ci/ml}$)	(Bq/m^3)
Te-133 ¹	12.45 min	5.E-06	2.E+05
Te-133m ¹	55.4 min	2.E-06	7.E+04
Te-134 ¹	41.8 min	5.E-06	2.E+05
I-122 ²	3.62 min	5.E-06	2.E+05
I-128 ¹	24.99 min	5.E-05	2.E+06
I-132 ¹	2.30 h	2.E-06	7.E+04
I-134 ¹	52.6 min	1.E-06	4.E+04
I-135 ¹	6.61 h	7.E-07 ⁶	3.E+04 ⁶
I-136 ²	83 s	1.E-06	4.E+04
Xe-122	20.1 h	8.E-05	3.E+06
Xe-123	2.14 h	7.E-06	3.E+05
Xe-125	16.8 h	2.E-05	7.E+05
Xe-127	36.406 d	1.E-05	4.E+05
Xe-129m	8.89 d	2.E-04	7.E+06
Xe-131m	11.84 d	5.E-04	2.E+07
Xe-133	5.245 d	1.E-04	4.E+06
Xe-133m	2.19 d	1.E-04	4.E+06
Xe-135	9.11 h	2.E-05	7.E+05
Xe-135m	15.36 min	1.E-05	4.E+05
Xe-137	3.83 min	2.E-05	7.E+05
Xe-138	14.13 min	4.E-06	1.E+05
Cs-126 ²	1.64 min	4.E-06	1.E+05
Cs-129 ¹	32.06 h	1.E-05 ⁶	4.E+05 ⁶
Cs-138 ¹	32.2 min	2.E-06	7.E+04
Cs-139 ²	9.40 min	1.E-05	4.E+05
Ba-137m ²	2.552 min	7.E-06	3.E+05
Ba-141 ¹	18.27 min	5.E-06	2.E+05
Ba-142 ¹	10.70 min	5.E-06	2.E+05
La-142 ¹	95.4 min	1.E-06	4.E+04
Pr-144m ²	7.2 min	9.E-04	3.E+07



Air Immersion DAC			
Radionuclide	Half-Life	($\mu\text{Ci/ml}$)	(Bq/m^3)
Nd-149 ¹	1.73 h	1.E-05	4.E+05
Gd-162 ²	9.7 min	1.E-05	4.E+05
Td-162 ²	7.76 min	4.E-06	1.E+05
Dy-157 ¹	8.06 h	1.E-05	4.E+05
Re-182m ¹	12.7 h	4.E-06	1.E+05
Os-190m ²	9.9 min	3.E-06	1.E+05
Ir-190m ¹	3.2 h	8.E-05 ⁶	3.E+06 ⁶
Au-195m ²	30.6 s	2.E-05	7.E+05
Tl-200 ¹	26.1 h	3.E-06	1.E+05
Tl-207 ²	4.77 min	4.E-05 ³	1.E+06 ³
Tl-208 ²	3.053 min	1.E-06	4.E+04
Tl-209 ²	2.20 min	2.E-06	7.E+04
Tl-210 ²	1.30 min	1.E-06	4.E+04
Pb-204m ²	66.9 min	2.E-06	7.E+04
Bi-211 ²	2.13 min	1.E-04	4.E+06
Po-211 ²	0.516 s	5.E-04	2.E+07
Th-233 ²	22.3 min	1.E-04	4.E+06
Pa-234 ¹	6.70 h	2.E-06	7.E+04
Pa-234m ²	1.17 min	4.E-05 ³	1.E+06 ³
U-239 ¹	23.40 min	8.E-05 ⁶	3.E+06 ⁶
Np-240 ¹	65 min	4.E-06	1.E+05
Np-240m ²	7.4 min	1.E-05	4.E+05
Am-246 ¹	25.0 min	4.E-06	1.E+05

¹ Committed effective dose equivalent from inhalation is calculated in ICRP Publication 30, but the DAC value for external exposure to a contaminated atmospheric cloud is more restrictive than the DAC value for inhalation.

² Committed effective dose equivalent from inhalation is not calculated in ICRP Publication 30, but DAC value for external exposure to contaminated cloud should be more restrictive than DAC value for inhalation due to relatively short half-life of radionuclide.

³ DAC value is determined by limit on annual shallow dose equivalent to skin, rather than yearly limit on effective dose equivalent.

⁴ DAC value applies to radionuclide in vapor form only; DAC value for inhalation is more restrictive for radionuclide in inorganic form.

⁵ DAC value applies to radionuclide in inorganic or vapor form.

⁶ DAC value for exposure to contaminated atmospheric cloud is the same as DAC value for inhalation.



Appendix 2F: Values For Establishing Sealed Radioactive Source Accountability And Radioactive Material Posting And Labeling Requirements

The data presented in Appendix 2F are to be used for identifying accountable sealed radioactive sources and radioactive material areas as those terms are defined at § 835.2(a), establishing the need for radioactive material area posting in accordance with § 835.603(g), and establishing the need for radioactive material labeling in accordance with § 835.605.

Note: The data in this table are listed in alphabetical order by nuclide.

Nuclide	Activity (μCi)	Nuclide	Activity (μCi)	Nuclide	Activity (μCi)
Ac-227	1.5E+00	Cl-36	4.6E+05	Ge-68	5.7E+02
Ag-105	2.1E+06	Cm-241	6.8E+04	H-3	1.6E+08
Ag-108m	1.8E+01	Cm-242	5.8E+02	Hf-172	3.1E+04
Ag-110m	2.2E+01	Cm-243	3.3E+01	Hf-175	1.8E+06
Al-26	1.6E+01	Cm-244	4.0E+01	Hf-178m	4.1E+03
Am-241	2.3E+01	Cm-245	2.2E+01	Hf-181	3.5E+02
Am-242m	2.4E+01	Cm-246	2.2E+01	Hf-182	3.0E+03
Am-243	2.3E+01	Cm-247	2.4E+01	Hg-194	3.5E+04
As-73	5.4E+02	Cm-248	6.0E+00	Hg-203	4.9E+02
Au-195	4.8E+02	Cm-250	1.1E+00	Ho-166m	2.2E+01
Ba-133	5.2E+01	Co-56	4.0E+01	I-125	3.5E+02
Be-10	2.8E+04	Co-57	2.3E+02	I-129	1.8E+02
Be-7	3.2E+03	Co-58	1.4E+02	In-114m	7.8E+02
Bi-207	1.7E+01	Co-60	1.8E+01	Ir-192	1.4E+02
Bi-208	1.5E+01	Cs-134	2.7E+01	Ir-192m	2.6E+04
Bi-210m	1.3E+03	Cs-135	2.2E+06	Ir-194m	2.7E+01
Bk-247	1.7E+01	Cs-137	6.0E+01	K-40	2.8E+02
Bk-249	7.2E+03	Dy-159	4.1E+06	La-137	1.1E+05
C-14	4.8E+06	Es-254	6.3E+01	Lu-173	4.4E+05
Ca-41	7.4E+06	Es-255	4.6E+04	Lu-174	2.5E+05
Ca-45	1.5E+06	Eu-148	7.0E+05	Lu-174m	3.9E+05
Cd-109	1.6E+02	Eu-149	5.3E+06	Lu-177m	5.8E+01
Cd-113m	6.5E+03	Eu-152	3.1E+01	Md-258	6.0E+02



Nuclide	Activity (μCi)	Nuclide	Activity (μCi)	Nuclide	Activity (μCi)
Cd-115m	1.0E+04	Eu-154	3.1E+01	Mn-53	2.0E+07
Ce-139	2.4E+02	Eu-155	3.7E+02	Mn-54	6.5E+01
Ce-141	2.4E+03	Fe-55	3.7E+06	Mo-93	7.7E+01
Ce-144	1.5E+03	Fe-59	2.0E+02	Na-22	1.9E+01
Cf-248	2.0E+02	Fe-60	1.3E+04	Nb-91	7.0E+01
Cf-249	1.7E+01	Fm-257	4.3E+02	Nb-91m	3.6E+02
Cf-250	3.8E+01	Gd-146	2.6E+05	Nb-92	1.8E+01
Cf-251	1.7E+01	Gd-148	3.0E+01	Nb-93m	4.4E+02
Cf-252	6.4E+01	Gd-151	1.1E+06	Nb-94	2.3E+01
Cf-254	3.4E+01	Gd-153	2.1E+02	Nb-95	3.4E+02
Ni-59	7.5E+06	Re-184	2.6E+02	Tc-97m	3.6E+02
Np-235	1.2E+02	Re-184m	1.5E+02	Tc-98	2.5E+01
Np-236	2.2E+01	Re-186m	2.8E+05	Tc-99	6.8E+06
Np-237	1.9E+01	Rh-101	2.5E+05	Te-121m	1.9E+02
Os-185	1.4E+02	Rh-102	8.3E+04	Te-123m	2.8E+02
Os-194	1.5E+04	Rh-102m	2.1E+05	Te-125m	4.4E+02
Pa-231	7.8E+00	Ru-103	4.4E+02	Te-127m	8.0E+02
Pb-202	1.0E+05	Ru-106	2.1E+04	Te-129m	2.3E+03
Pb-205	9.1E+01	S-35	4.0E+06	Th-228	2.9E+01
Pb-210	9.2E+01	Sb-124	9.1E+01	Th-229	4.7E+00
Pd-107	7.8E+05	Sb-125	6.8E+01	Th-230	3.1E+01
Pm-143	1.3E+02	Sc-46	6.2E+01	Th-232	6.1E+00
Pm-144	2.9E+01	Se-75	6.4E+01	Ti-44	1.6E+02
Pm-145	2.6E+02	Se-79	1.0E+06	Tl-204	2.2E+04
Pm-146	4.5E+01	Si-32	9.9E+03	Tm-170	8.4E+03
Pm-147	2.5E+05	Sm-145	9.1E+05	Tm-171	2.8E+04
Pm-148m	1.1E+02	Sm-146	1.2E+02	U-232	1.5E+01
Po-209	6.3E+03	Sm-151	2.5E+05	U-233	7.4E+01
Po-210	1.1E+03	Sn-113	3.1E+02	U-234	7.5E+01
Pt-193	4.4E+07	Sn-119m	3.3E+02	U-235	6.7E+01
Pu-236	6.9E+01	Sn-121m	8.7E+05	U-236	8.0E+01
Pu-237	3.3E+02	Sn-123	1.3E+04	U-238	8.4E+01
Pu-238	2.5E+01	Sn-126	1.8E+02	V-49	2.9E+07
Pu-239	2.3E+01	Sr-85	1.2E+02	W-181	1.1E+03



Nuclide	Activity (μCi)	Nuclide	Activity (μCi)	Nuclide	Activity (μCi)
Pu-240	2.3E+01	Sr-89	2.4E+05	W-185	3.9E+06
Pu-241	1.2E+03	Sr-90	7.7E+03	W-188	6.4E+04
Pu-242	2.4E+01	Ta-179	1.5E+06	Y-88	3.4E+01
Pu-244	2.5E+01	Ta-182	7.3E+01	Y-91	5.0E+04
Ra-226	1.2E+03	Tb-157	2.5E+03	Yb-169	5.5E+02
Ra-228	2.1E+03	Tb-158	3.9E+04	Zn-65	1.1E+02
Rb-83	9.2E+01	Tb-160	1.2E+02	Zr-88	1.2E+02
Rb-84	2.0E+02	Tc-95m	1.3E+02	Zr-93	3.1E+04
Re-183	5.4E+02	Tc-97	8.1E+01	Zr-95	2.0E+02

Any alpha emitting radionuclide not listed above and mixtures of alpha emitters of unknown composition have a value of 10 microcuries.

Any radionuclide other than alpha emitting radionuclides not listed above and mixtures of beta emitters of unknown composition have a value of 100 microcuries.

Note: Where there is involved a combination of radionuclides in known amounts, derive the value for the combination as follows: determine, for each radionuclide in the combination, the ratio between the quantity present in the combination and the value otherwise established for the specific radionuclide when not in combination. If the sum of such ratios for all radionuclides in the combination exceeds unity (1), then the accountability criterion has been exceeded.



Chapter 3: Conduct of Radiological Work

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REFERENCES

The following reference documents are used for guidance regarding this chapter. The CFR web site <http://www.gpoaccess.gov/cfr/index.html> contains further information regarding this reference material.

10 CFR 835

PART 1 Planning Radiological Work

310 Planning

Measures are taken to maintain radiation exposure in controlled areas as low as is reasonably achievable through facility and equipment design and administrative control. The primary methods used at Jefferson Lab are physical design features (e.g., confinement of the beam to an underground enclosure, prevention of access by interlock, ventilation control, and shielding).

Administrative controls and procedural requirements are used only as supplemental methods to control radiation exposure. For specific activities where use of physical design features is demonstrated to be impractical, administrative controls and procedural requirements are used to maintain radiation exposures ALARA.

In addition to normal safety and good housekeeping practices, when working with radiation producing equipment or radioactive material, personnel exposure can be minimized by:

1. reducing the time spent in radiation areas - this can be done by job planning, staging all necessary tools and equipment, etc.
2. maximizing the distance from the source of radiation - the work site can be moved away from the source of radiation (if possible) or persons can keep as far from the source as possible.
3. maximizing the amount of shielding between workers and radiation source - if the work site cannot be moved, shielding may be used to reduce the intensity of the radiation field.
4. minimizing the quantity of radioactive material.

311 Requirements

1. Technical requirements for the conduct of work, including construction, modifications, operations, and maintenance and decommissioning, shall incorporate radiological criteria to ensure safety and maintain radiation exposures ALARA. To accomplish this, the design and planning processes should incorporate radiological considerations in the early planning stages. The checklist in [Appendix 3A](#) is helpful in reducing occupational radiation exposure.
2. **At all times**, the instructions given by any Radiation Control Group representative or by this Manual shall be followed. Failure to do so may result in disciplinary actions including, but not limited to: notation of infraction in the employee's records, immediate revocation of Radiological Training qualification (not subject to grace periods), suspension of source handling privileges, or dismissal. The final recommendation shall be at the discretion of the Radiation Control Manager. Action on any recommendation by the Radiation Control Manager is the responsibility of the employee's supervisor in consultation with the Division Management and the Human Resources Department.

312 Planning for Maintenance, Operations and Modifications

1. Maintenance and modification plans and procedures shall be reviewed to identify and incorporate radiological requirements, such as engineered controls and dose and contamination reduction considerations. Performance of this review is the responsibility of line management, with support and concurrence from the Radiation Control Group.
2. Trigger levels requiring formal radiological review of nonroutine or complex work activities include:
 - a. Estimated dose greater than 250 mrem for an individual for the activity.
 - b. Estimated collective dose greater than 1 person-rem.
 - c. Predicted airborne radioactivity dose in excess of 100 mrem.
 - d. Work area removable contamination greater than 1000 times the values in [Table 2-2](#)
 - e. Entry into areas where dose rates exceed 1 rem/hour.
 - f. Potential unexpected or excessive radioactive releases to the environment.
3. For activities not exceeding the thresholds in the above paragraph, performance of the review and documentation of identified radiological requirements may be conducted as part of the Radiological Work Permit process (see [Article 321](#)).
4. Tasks with the potential to exceed the above trigger levels in No. 2 shall undergo a formal, documented radiological review that is approved by the JRRP. They shall not exceed individual dose limits specified in [Article 213](#). Among other considerations, this review shall consider the following as appropriate:
 - a. Inclusion of Radiological Control Hold Points in the technical work documents
 - b. Elimination or reduction of radioactivity through system or work area decontamination
 - c. Use of work processes and special tooling to reduce time in the work area
 - d. Use of engineered controls to minimize the spread of contamination and generation of airborne radioactivity
 - e. Specification of special radiological training or monitoring requirements
 - f. Use of mock-ups for high exposure or complex tasks
 - g. Engineered, design and use of temporary shielding to reduce radiation levels
 - h. Walkdown or dry-run of the activity using applicable procedures
 - i. Staging and preparation of necessary materials and special tools
 - j. Maximization of prefabrication and shop work
 - k. Review of abnormal and emergency procedures and plans
 - l. Identification of points where signatures and second party or independent verifications are required
 - m. Establishment of success or completion criteria, with contingency plans to anticipate difficulties
 - n. Development of a pre-job estimate of collective exposure to be incurred for the job
 - o. Provisions for waste minimization and disposal.
5. Radiological requirements identified as part of the above radiological review should be documented in the job plans, procedures or work packages.

Optimization techniques, including cost-benefit analysis, represent a fundamental part of radiological design analysis and work review. For review of minor activities with low associated doses, a cost-benefit evaluation is an intrinsic part of the engineering review process and a detailed evaluation is not necessary. For review and planning of major tasks involving higher collective dose expenditures, a detailed and documented evaluation should be performed.

313 Infrequent or First-Time Activities

1. With respect to routine, recurring process operations, special management attention should be directed to radiological activities that are infrequently conducted or represent first-time operations and could result in significant doses to workers. Planning for such activities should include:
 - a. Formal radiological review in accordance with [Article 312.4](#)
 - b. Senior management review directed toward anticipation of concerns and emphasis and specification of protective measures
 - c. Review and approval by the Jefferson Lab Radiation Review Panel
 - d. Enhanced line and Radiological Control management oversight during the initiation and conduct of the work.
2. Radiography may be used to check, among other things, the integrity of welds on material at Jefferson Lab. Prior to the commencement of radiographic operations, applicable procedures shall be reviewed. A representative of the RCG should be responsible for verifying the establishment of a controlled area around the radiography site and for controlling personnel access to the area.

314 Temporary Shielding

1. Temporary shielding is defined herein as shielding used for personnel protection from radiation that may be non-destructively disassembled or removed. Some examples are: water or lead shielding around dumps; non-mortared cinder block walls, and movable shield walls or lead baffles. This list is NOT all-inclusive.
2. Installed temporary shielding should be visibly marked or labeled with the following or equivalent wording: "Radiological Control Group Shielding Configuration – Notice: This configuration shall not be moved or altered in any way without RCG approval. For assistance call RCG at 876-1743."
3. Temporary shielding visibly marked or labeled as in Article 314.2 shall not be disturbed without prior concurrence of the Radiation Control Group. Disturbing such shielding may result in excess radiation exposure to personnel, and may result in disciplinary action as described in [Article 311.2](#).
4. The installation, use and removal of temporary shielding shall be controlled by policy and should be controlled by procedure when the work could cause radiation levels that would result in the need for an RWP. See [Article 322](#).
5. The effects of the additional weight of temporary shielding on systems and components should be evaluated and established to be within the design basis prior to installation.
6. Installed temporary shielding should be periodically inspected and surveyed to verify effectiveness and integrity.
7. Radiation surveys should be performed during the alteration or removal of installed temporary shielding.
8. Installed temporary shielding should be periodically evaluated to assess the need for its removal or replacement with permanent shielding.
9. Site procedures may identify specific shielding applications, such as the shielding of low activity sources or samples, that fall outside the recommendations of this Article.



315 Work Control Documents

1. Work control documents such as Temporary Operational Safety Procedures (TOSPs), Operational Safety Procedures (OSPs), Radiation Work Permits (RWPs), and Radiation Control Operating Procedures (RCOPs) (a special type of Standard Operating Procedure (SOP) required when the primary hazard is radiological) shall be used as necessary to support radiological control operations. These technical work documents reflect the relative level of hazard for the activity under consideration, define the prerequisites including equipment and training as necessary, and outline the steps necessary for safe work.
2. Work control documents used to control radiological work activities must be reviewed and approved by the Radiation Control Group.
3. Radiological Control Hold Points must be incorporated into work control documents for steps that require action by the Radiation Control Group to prevent radiation exposures in excess of Administrative Control Levels, high airborne radioactivity concentrations, or the release of radioactivity to the environment.

316 Minimization of Internal Exposure

The minimization and control of internal exposure is discussed in [Article 223](#). Estimates of internal exposure shall be conducted in accordance with [Article 223](#) and should be minimized using the following hierarchy of controls:

Regarding the control of airborne radioactive material, and in any situation, to control the inhalation of such material by workers to levels that are ALARA; confinement and ventilation should be used.

1. Under normal conditions, releases of radioactive material to the workplace atmosphere should be avoided. Wherever practicable, engineered controls including containment of radioactive material at the source and ventilation should be the primary methods of minimizing airborne radioactivity and internal exposure to workers. In any case, the internal exposure of workers to radioactive material should be maintained to levels that are ALARA.
2. Administrative controls, including access restrictions and the use of specific work practices designed to minimize airborne contamination, should be used as secondary methods to minimize worker internal exposure.
3. When engineered and administrative controls have been applied and the potential for exposure to airborne radioactivity still exists, respiratory protection should be considered for use in limiting internal exposures. Use of respiratory protection should be considered under the following conditions:
 - a. Entry into posted Airborne Radioactivity.
 - b. During breach of contaminated systems or components.
 - c. Work in areas or on equipment with removable contamination levels greater than 100 times the values in [Table 2-2](#).
4. The selection of respiratory protection equipment should include consideration of worker safety, comfort and efficiency. The use of positive pressure respiratory protection devices is recommended wherever practicable to alleviate fatigue and increase comfort.



5. In specific situations the use of respiratory protection may be contraindicated due to physical limitations or the potential for significantly increased external exposure. In such circumstances specific evaluations shall be performed to determine expected exposure contributions from internal/external sources.
6. In every case, consideration should be given to the effect of the use of respiratory devices (with respect to decreased worker efficiency and safety) on the total dose anticipated during an activity, and efforts should be made to keep the total dose ALARA.

PART 2 Work Preparation

321 Radiological Work Permits

The Radiological Work Permit (RWP) is a work control document used to establish radiological controls for intended work activities. The RWP informs workers of area radiological conditions and entry requirements and provides a mechanism to relate worker exposure to specific work activities. The RWP should include the following information:

1. Description of work
2. Work area radiological conditions
3. Dosimetry requirements
4. Pre-job briefing requirements, as applicable
5. Training requirements for entry
6. Personnel protective equipment requirements
7. Radiological Control coverage requirements and stay time controls, as applicable
8. Limiting radiological conditions that may void the RWP
9. Special dose or contamination reduction considerations
10. Special personnel monitoring considerations
11. Technical work document number, as applicable
12. Unique identifying number
13. Date of issue and expiration
14. Authorizing signatures

322 Use of Radiological Work Permits

Dose tracking through a radiation work permit should be established whenever the area which will be occupied by the trunk of a worker's body (usually 30 centimeters (1 foot) from the work piece) is greater than 25 mrem/hr, the total estimated dose to a worker exceeds 25 mrem, or the workpiece measures 250 mR/hr on contact.

1. RWPs **shall** be used to control the following activities:
 - a. Entry into High and Very High Radiation Areas
 - b. Entry into High Contamination Areas and Contamination Areas
 - c. Handling of materials with removable contamination that exceeds the values of [Table 2-2](#)
 - d. Any process identified by the RCG to need an RWP, such as first-time activities
2. Job-specific RWPs shall be used to control non-routine operations or work in areas with changing radiological conditions. The job-specific RWP shall remain in effect only for the duration of the job. If the job is repetitive, a standing RWP may be used.
3. General RWPs may be used to control minor radiological work activities, tours, and inspections in areas with well-characterized and stable radiological conditions. General RWPs should not be approved for periods longer than 1 year.



4. Radiological surveys should be reviewed routinely to evaluate adequacy of RWP requirements. RWPs shall be updated if radiological conditions change to the extent that protective requirements need modification.
5. RWPs should be posted at the access point(s) to the applicable radiological work area, and shall be made available at the worksite.
6. Workers shall sign that they have read, understand and shall comply with the RWP prior to initial entry to the area and after any revisions to the RWP.
7. Worker pocket or electronic dosimeter readings should be recorded in a format that identifies and provides linkage to the applicable RWP.

323 Radiological Work Permit Preparation

1. The responsibility for ensuring adequate planning and control of work activities resides with line management. The lead work group responsible for the planned activity or for the area should initiate the preparation of the RWP.
2. RWPs shall be reviewed and approved by the Radiation Control Group.
3. The RWP should be based on current radiological surveys and anticipated radiological conditions.
4. The RWP shall be approved by the supervisor responsible for the work or area and the appropriate Radiological Control supervisor. Revisions or extensions to RWPs shall be subject to the same approval process.

324 Pre-Job Briefings

1. At a minimum, pre-job briefings shall be held prior to the conduct of work anticipated to exceed the trigger levels identified in [Article 312.2](#).
2. At a minimum, the pre-job briefing should include:
 - a. Scope of work to be performed
 - b. Radiological conditions of the workplace
 - c. Procedural and RWP requirements
 - d. Special radiological control requirements
 - e. Radiologically limiting conditions, such as contamination or radiation levels that may void the RWP
 - f. Radiological Control Hold Points
 - g. Communications and coordination with other groups
 - h. Provisions for housekeeping and final cleanup
 - i. Emergency response provisions.
3. Pre-job briefings should be conducted by the cognizant work supervisor and knowledgeable RCG Representative.
4. All persons utilizing a RWP requiring a pre-job briefing shall be briefed prior to using the RWP.
5. A summary of topics discussed and attendance at the pre-job briefing should be documented.



325 Personal Protective Equipment and Clothing

For the purposes of this Supplement, personal protective equipment (alternately, personnel protective equipment) consists of clothing, respiratory equipment, portable containments, and other such devices.

1. Personnel shall wear protective clothing during the following activities:
 - a. Handling of contaminated materials with removable contamination in excess of [Table 2-2](#) levels
 - b. Work in Contaminated Areas
 - c. As directed by the Radiation Control Group or as required by the RWP.
2. Nondisposable protective equipment designated for radiological control shall be:
 - a. Marked in accordance with [Article 481](#)
 - b. Used only for radiological control purposes
3. Personal Protective Equipment shall be selected as prescribed by the controlling RWP. General guidelines for protective clothing selection and use are provided in [Appendix 3C](#) and in [Table 3-1](#).
4. The use of lab coats as radiological protective clothing is appropriate for limited applications such as those discussed in [Appendix 3C](#) where the potential for personal contamination is limited to the hands, arms, and upper front portion of the body. Coveralls should be used as protective clothing for performing physical work activities in Contaminated or Airborne Radioactivity Areas.
5. Instructions for donning and removing protective clothing should be posted at the appropriate areas for routinely accessed contamination areas.
6. The use of Personal Protective Equipment or clothing for Radiological Controls beyond that authorized by the Radiation Control Group may detract from work performance and is contrary to ALARA principles and waste minimization practices. Such use should be avoided.

PART 3 Entry and Exit Requirements

The degree of personnel entry control should be commensurate with existing and potential radiological hazards within the area.

The Radiation Control Group uses administrative procedures, including incorporation of entry and exit requirements into work control documents, RWPs and RCOPs, to ensure these requirements are met. These administrative procedures include actions essential to ensure the effectiveness and operability of interlocks, barricades, devices, alarms, locks, and other devices used to control entry and exit for radiological areas.

Under no circumstance shall control(s) be installed at any radiological area exit that would prevent rapid evacuation of personnel under emergency conditions.

331 Controlled Areas

Successful completion of General Employee Radiological Training or the equivalent as approved by the RCG is required for unescorted entry into Controlled Areas. Untrained visitors must be escorted at all times while in Controlled Areas. Visitors shall not enter into posted Radiation Areas without the express permission of the RCG.

332 Radiological Buffer Areas

1. Minimum requirements for unescorted entry into Radiological Buffer Areas shall include the following:
 - a. Radiological Worker I training
 - b. Personnel dosimetry, as defined by an RCG member.
2. Personnel who exit a Radiological Buffer Area containing Contamination Areas, High Contamination Areas, or Airborne Radioactivity Areas should monitor as specified in Article 338.

333 Radioactive Material Areas

General Employee Radiological Training is required for unescorted entry into Radioactive Material Areas. Other requirements may apply depending on the use and quantity of the radioactive material and the dose equivalent rate in the area. These requirements will be contained in the applicable postings for the area.

334 Entry into Radiologically Controlled Areas

Radiologically Controlled Areas (RCAs) are areas where radiological controls are implemented. These controls may include training, dosimetry, work-specific controls, or others. Routine occupancy in RCAs may result in a dose greater than 100 mrem per year to an employee. Radiologically Controlled Areas may or may not contain Radiation, High Radiation and Very High Radiation Areas, Exclusion Areas, Radioactive Material Areas, and Contamination Areas.

1. A “radiological area” is defined as a Radiation Area, High Radiation Area, Very High Radiation Area, Contamination Area, or High Contamination Area, or an Airborne Radioactivity Area. Personnel entry control shall be maintained for each radiological area. The degree of personnel entry control shall be commensurate with existing and potential radiological hazards within the area. One or more of the following methods shall be used to ensure personnel entry control:
 - a. Signs and barricades;
 - b. Control devices on entrances;
 - c. Conspicuous visual and/or audible alarms;
 - d. Locked entrance ways; or
 - e. Administrative procedures.
2. Written authorizations, such as RWPs, shall be required to control entry into and perform work within radiological areas. These authorizations shall specify radiation protection measures commensurate with the existing and potential hazards.
3. Minimum requirements for unescorted entry into a Radiologically Controlled Area shall include the following:
 - a. Satisfactory completing of Radiological Worker I Training
 - b. Properly attached personnel dosimetry
4. Minimum requirements for unescorted entry into Radiation Areas shall include the following:
 - a. Satisfactory completing of Radiological Worker I training
 - b. Worker's signature on the Radiological Work Permit (RWP), as applicable
 - c. Properly attached personnel dosimetry.
5. Physical controls to prevent inadvertent or unauthorized access to High and Very High Radiation Areas shall be maintained in accordance with [Appendix 3B](#). **No controls shall be installed at any radiological area exit that would prevent rapid evacuation of personnel under emergency conditions.**
6. Minimum requirements for entry into High Radiation Areas shall include the following:
 - a. The area shall be monitored as necessary during access to determine the exposure rates to which the individuals are exposed
 - b. Satisfactory completing of Radiological Worker I Training
 - c. Worker's signature on the RWP
 - d. Properly attached personnel and supplemental dosimeters (for immediate dose estimates)



7. In addition to the physical controls to prevent inadvertent or unauthorized access to High and Very High Radiation Areas in accordance with Appendix 3B, the minimum requirements for entry into High Radiation Areas where dose rates exist such that a worker could exceed a whole body dose of 1 rem in one hour shall include the following items in the RWP:
 - a. A determination of the worker's current exposure, based on primary and supplemental dosimeter readings
 - b. Pre-job briefing, as applicable
 - c. Review and determination by the Radiation Control Group regarding the required level of Radiological Control Technologist coverage.
8. Prior to the first entry into any area where a source could create a very high radiation area, a survey shall be made after the source has been secured or shielded to verify the very high radiation field has been terminated. For accelerator enclosure entry after shutdown, a radiation survey begins upon entry to locate radiological areas. This survey also serves as an indicator that the accelerator is shut down and prompt radiation producing operations have terminated. In some cases, such as when access is restricted to an area where activation of accelerator components is negligible, alarming fixed instrumentation or personnel electronic alarming pocket dosimeters may be used to indicate that prompt radiation production has terminated.
9. The Crew Chief and the RCG shall be notified prior to personnel entry to areas where operational or system changes made by operations personnel could result in significantly increased area dose rates.
10. The number, issue, and use of keys shall be strictly controlled where locked entryways are used to control access to High and Very High Radiation Areas. The loss of any key for these areas shall be immediately addressed by the RCG.
11. Inspections of the physical access controls to accessible High and Very High Radiation Areas shall be made at appropriate intervals to verify controls are adequate to prevent unauthorized entry.

335 Contaminated and Airborne Radioactivity Areas

1. Minimum requirements for unescorted entry into Contaminated Areas shall include the following:
 - a. Radiological Worker II training
 - b. Worker's signature on the RWP, as applicable
 - c. Protective clothing
 - d. Personnel dosimetry, as appropriate.
2. Minimum requirements for unescorted entry into Airborne Radioactivity Areas shall include the following:
 - a. Radiological Worker II training
 - b. Worker's signature on the RWP
 - c. Protective clothing and respiratory protection, as specified by the RWP
 - d. Pre-job briefing for Highly Contaminated or Airborne Radioactivity Areas, as applicable
 - e. Personnel dosimetry, as appropriate.



3. Personnel exiting Contaminated or Airborne Radioactivity Areas shall use appropriate monitoring to detect and prevent the spread of contamination. The following will be performed by individuals exiting radiological areas established to control removable contamination and/or airborne radioactivity as appropriate:
 - a. Remove protective clothing as specified in [Appendix 3C](#)
 - b. Monitor to detect personnel contamination in accordance with [Article 338](#)
 - c. Tools or equipment being removed from the area shall be monitored for release in accordance with [Article 421](#).
4. Exit points from Contaminated or Airborne Radioactivity Areas should include the following:
 - a. Step-off pad located outside the exit point, contiguous with the area boundary
 - b. Step-off pads maintained free of radioactive contamination
 - c. Labeled containers inside the area boundary for the collection of protective clothing and equipment
 - d. Contamination monitoring equipment located as close to the step-off pad as background radiation levels permit.
5. Multiple step-off pads should be used at the exits from High Contamination Areas. Use of multiple step-off pads is described in [Appendix 3C](#).
6. Protective clothing and monitoring requirements specific to benchtop work, laboratory fume hoods, sample stations and gloveboxes are identified in [Article 347](#).

336 Visitor Entry Restrictions

1. Signs and training identify area entry requirements and access restrictions for visitors.
2. Visitors with a demonstrated need to enter the following areas may be allowed access if such access is controlled with a combination of training and the use of escorts trained for the specific area:
 - a. Radiation Areas
 - b. Radioactive Material Areas
3. Visitors shall be prevented from entering High Radiation Areas and Very High Radiation Areas and shall be prohibited access to Contaminated, Highly Contaminated, and Airborne Radioactivity Areas.
4. Training requirements for visitors are identified in [Article 622](#).

337 Controlling the Spread of Contamination

The following measures should be used to prevent the spread of contamination from Contaminated Areas and Airborne Radioactivity Areas:

1. Use solid barriers to enclose areas wherever practicable
2. Mark and secure items such as hoses and cords that cross the boundary
3. Control and direct airflow from areas of lesser to greater removable contamination
4. Use engineered controls and containment devices such as glovebags, gloveboxes, tents, and HEPA-filtered ventilation.

338 Monitoring for Personnel Contamination

Jefferson Lab will use appropriate monitoring to detect and prevent the spread of contamination. Monitoring will be performed by individuals exiting radiological areas established to control removable contamination and/or particulate airborne radioactivity.

1. Personnel shall perform a whole body survey under the following conditions:
 - a. Immediately upon exiting Contaminated Areas and Airborne Radioactivity Areas (where established for particulate radioactivity)
 - b. As directed by the RWP or the Radiation Control Group
2. In addition to the above, personnel exiting a Contamination, High Contamination or Airborne Radioactivity Areas should, at a minimum, perform a hand and foot frisk.
3. Where monitoring cannot be performed at the exit from Contaminated Areas or Airborne Radioactivity Areas due to high background radiation levels, personnel shall:
 - a. Remove all protective equipment and clothing at the exit
 - b. Proceed directly to the nearest designated monitoring station
 - c. Conduct a whole body survey.
4. Personnel monitoring shall be performed after removal of protective clothing and prior to washing or showering.
5. Personnel monitoring shall be performed using instruments that meet the minimum detection requirements of [Article 221.2](#). Guidelines for personnel frisking are provided in [Appendix 3D](#).
6. Guidelines for personnel monitoring are provided in [Appendix 3D](#).
7. Personal items, such as notebooks, papers and flashlights, shall be subject to the same monitoring requirements as the person carrying them.
8. Instructions for personnel monitoring should be posted adjacent to personnel monitoring instruments or monitors.

PART 4 Radiological Work Controls

Authorization is required to perform work within radiological areas. This authorization is contained in RWPs and other work control documents which include specific radiation protection measures.

341 Requirements

1. Radiological work activities shall be conducted as specified by the RWP and other work control documents.
2. Prerequisite conditions, such as tag-outs and system isolation, shall be verified in accordance with the work control documents before work is initiated.

342 Work Conduct and Practices

1. Contamination levels caused by ongoing work shall be monitored and should be maintained ALARA. Work should be curtailed and decontamination performed at pre-established levels, taking into account worker exposure.
2. Tools and equipment should be inspected to verify operability before being brought into Contaminated or Airborne Radioactivity Areas.
3. The use of radiologically clean tools or equipment in Contaminated or Airborne Radioactivity Areas should be minimized (e.g., by the implementation of a contaminated tool crib). When such use is necessary, tools or equipment with complex or inaccessible areas should be wrapped or sleeved to minimize contamination.
4. Engineered controls, such as containment devices, portable or auxiliary ventilation and temporary shielding, should be installed in accordance with the technical work documents and inspected prior to use.
5. Hoses and cables entering the work area should be secured to prevent the spread of contamination or safety hazards.
6. The identity of components and systems should be verified prior to work.
7. Work activities and shift changes should be scheduled to prevent idle time in radiation areas.
8. Where practicable, parts and components should be removed to areas with low dose rates to perform work.
9. Upon identification of radiological concerns, such as inappropriate work controls or procedural deficiencies, workers shall immediately report the concern to line supervision or the Radiation Control Group.
10. Requirements for area cleanup should be included in the work control documents. Work activities should not be considered complete until support material and equipment have been removed and the area has been returned to at least pre-work status.
11. To minimize intakes of radioactive material by personnel, smoking, eating, or chewing should not be permitted in Radiation Areas, High Radiation Areas, Contamination Areas, potentially contaminated areas, Airborne Radioactivity Areas, or Radioactive Material Areas.

343 Logs and Communications

1. Radiological Control personnel shall document abnormal radiological situations, and should maintain logs on work controlled by work control documents such as Radiological Work Permits (RWPs), which include the status of work activities and other relevant information.
2. During continuous or extended daily operations, oncoming Radiological Control personnel should review logs and receive a turnover briefing from the personnel they are relieving.
3. Communication systems required by the Radiological Work Permit or work control document should be checked for operability before being brought into the work area and periodically during work.
4. Workers shall keep Radiological Control personnel informed of the status of work activities that affect radiological conditions.

344 Review of Work in Progress

1. As part of their normal work review, work supervisors should periodically review ongoing jobs to ensure prescribed radiological controls are being implemented.
2. Radiological Control personnel should conduct frequent tours of the workplace to review the adequacy of radiological work practices, posting and area controls.
3. During the performance of jobs for which a pre-job dose estimate was made, the Radiation Control Group, in cooperation with line management, should periodically monitor collective dose accumulation and compare it with the pre-job dose estimate. Differences should be reviewed to identify causes and assess the need for corrective actions.

345 Stop Radiological Work Authority

1. Radiological Control Technologists and their supervisors, line supervision, and any worker through their supervisor, has the authority and responsibility to stop radiological work activities for any of the following reasons:
 - a. Inadequate radiological controls,
 - b. Radiological controls not being implemented, or
 - c. Radiological Control Hold Point not being satisfied.
2. Stop radiological work authority shall be exercised in a justifiable and responsible manner (e.g., barring access to the area, revoking of the RWP, or revoking of individual training).
3. Once radiological work has been stopped, it shall not be resumed until proper radiological control has been reestablished.
4. Resumption of radiological work requires the approval of the line manager responsible for the work and the Radiation Control Manager.



346 Response to Abnormal Situations

1. An emergency is defined by the Jefferson Lab EH&S Manual as any real or potential condition, injury, illness, or accident at Jefferson Lab which threatens the personnel, property, or environment within Jefferson Lab boundaries or the adjacent properties and communities. An emergency in which there is a real or potential exposure to radiation or release of radioactive material in excess of applicable guidelines is considered to be a **radiation emergency**. A **radiation emergency** can occur as a result of accelerator operations or as a result of the use or handling of activated material, radioactive material, or radioactive sources.
2. In the event of a **radiation emergency** that results from **accelerator operations**, the Crew Chief shall be notified at the Machine Control Center, ext. 7047 or ext. 7050. The Crew Chief shall then notify the appropriate personnel as indicated in the Jefferson Lab *EH&S Manual* including the Radiation Control Group (RCG) using the following information.

Radiation Control Group Notification Information (as of January 2004) Current information may be found at <http://www.jlab.org/accel/RadCon/personnel.html>

Name	Mail Stop	Phone	Pager
Erik Abkemeier (RCM)	MS 5A	ext. 7551	584-7551
Keith Welch	MS 52B	ext. 7212	584-7212

24 Hour Cell Phone 757-876-1743
RCM Cell Phone 757-876-5342

In the event of a radiation emergency, the Radiation Control Group, as listed above, should be notified.

3. Response to increasing or unanticipated radiation levels, as identified by a supplemental dosimeter or Area Radiation Monitor Alarm, should include the following actions:
 - a. Stop work activities,
 - b. Alert others,
 - c. All personnel immediately exit the area, and
 - d. Notify Radiological Control personnel.
4. Response to personnel contamination should include the following actions:
 - a. Remain in the immediate area,
 - b. Notify Radiological Control personnel, and
 - c. Take actions that may be available to minimize cross-contamination, such as putting a glove on a contaminated hand.
5. Response to a spill of radioactive material should include the following actions:
 - a. Stop or secure the operation causing the spill,
 - b. Warn others in the area,
 - c. Isolate the spill area if possible,
 - d. Minimize individual exposure and contamination,
 - e. Secure unfiltered ventilation, and
 - f. Notify Radiological Control personnel.

For spills involving highly toxic chemicals, workers should immediately exit the area without attempting to stop or secure the spill. They should then promptly notify the Industrial Hygiene or the Lab Chemical Assistance team and Radiological Control personnel by calling the guard at x4444, then calling x7863.

347 Contamination Control

1. Control of material and equipment

- a. Except as provided in paragraphs (b) and (c) of this section, material and equipment in contamination areas, high contamination areas, and airborne radioactivity areas shall not be released to an area outside of a contamination area, high contamination area, or airborne radioactivity area if:
 - (1) Removable surface contamination levels on accessible surfaces exceed the removable surface contamination values specified in [Table 2-2](#); or
 - (2) Process knowledge suggests that the removable surface contamination levels on inaccessible surfaces are likely to exceed the removable surface contamination values specified in [Table 2-2](#).
- b. Material and equipment exceeding the removable surface contamination values specified in [Table 2-2](#) may be conditionally released for movement on-site from one radiological area for immediate placement in another radiological area only if appropriate monitoring is performed and appropriate controls for the movement are established and exercised.
- c. Material and equipment with fixed contamination levels that exceed the total surface contamination values specified in [Table 2-2](#) may be released for use in RCAs outside of radiological areas only under the following conditions:
 - (1) Removable surface contamination levels are below the removable surface contamination values specified in [Table 2-2](#); and
 - (2) The material or equipment is routinely monitored and clearly marked or labeled to alert personnel of the contaminated status.

2. Control of areas

- a. Appropriate controls shall be maintained and verified which prevent the inadvertent transfer of removable contamination to locations outside of radiological areas under normal operating conditions.
- b. Any area in which contamination levels exceed the values specified in [Table 2-2](#) shall be controlled in a manner commensurate with the physical and chemical characteristics of the contaminant, the radionuclides present, and the fixed and removable surface contamination levels.
- c. Areas accessible to individuals where the measured total surface contamination levels exceed, but the removable surface contamination levels are less than, corresponding surface contamination values specified in [Table 2-2](#) shall be controlled as follows when located outside of radiological areas:
 - (1) The area shall be routinely monitored to ensure the removable surface contamination level remains below the removable surface contamination values specified in [Table 2-2](#); and
 - (2) The area shall be conspicuously marked to warn individuals of the contaminated status.



- d. Individuals exiting contamination, high contamination, or airborne radioactivity areas shall be monitored, as appropriate, for the presence of surface contamination.
- e. Protective clothing shall be required for entry to areas in which removable contamination exists at levels exceeding the removable surface contamination values specified in [Table 2-2](#).

348 Controls for Benchtop Work, Laboratory Fume Hoods, Sample Stations and Gloveboxes

The following requirements are applicable to radiological work in localized benchtop areas, laboratory fume hoods, sample stations and glovebox operations located in areas that are otherwise contamination free when contamination levels associated with the operations exceed or are likely to exceed [Table 2-2](#) values.

1. A Radiological Work Permit (RWP) shall be issued to control radiological work in localized benchtop areas, laboratory fume hoods, sample sinks, and gloveboxes.
2. The following controls apply to localized bench top and laboratory fume hood operations:
 - a. Protective clothing shall, at a minimum, include lab coats and gloves. Gloves should be secured at the wrist as necessary.
 - b. Shoe covers should be considered based on the potential for floor contamination.
 - c. Workers should periodically monitor their hands during work.
 - d. Upon completion of work or prior to leaving the area, workers shall monitor those areas of their body that are potentially contaminated. At a minimum, this includes hands, arms, and front portions of the body. Workers should perform a whole body survey.
 - e. Install temporary shielding as appropriate.
 - f. When finished with operations, decontaminate and remove equipment.
3. The following controls apply to sample station operations:
 - a. Protective clothing shall, at a minimum, include gloves. Gloves should be secured at the wrist as necessary.
 - b. Shoe covers should be considered based on the potential for floor contamination.
 - c. If there is a potential for splashing or airborne radioactivity, such as when taking pressurized samples, additional controls such as rubber aprons, face shields, full protective clothing (PCs), or respiratory protection should be instituted.
 - d. Workers should periodically monitor their hands during work.
 - e. Upon completion of work or prior to leaving the area, workers shall monitor those areas of their body that are potentially contaminated. At a minimum, this includes hands, arms, and front portions of the body. Workers should perform a whole body survey.
4. The following controls apply to glovebox operations:
 - a. Gloveboxes should be inspected for integrity and operability prior to use.
 - b. Gloveboxes should be marked with, or survey measurements should be posted to identify, whole body and extremity dose rates, as appropriate.
 - c. Gloves in addition to those integral in the glove box should be worn when contamination levels in the glove box may exceed 100 times the [Table 2-2](#) value.
 - d. Shoe covers should be considered based on the potential for floor contamination.
 - e. Workers should periodically monitor their hands during work.
 - f. Upon completion of work or prior to leaving the area, workers shall monitor those areas of their body that are potentially contaminated. At a minimum, this includes hands, arms, and feet. Workers should perform a whole body survey.

349 Controls for Hot Particles

Hot particles are small, discrete, highly radioactive particles capable of causing extremely high doses to a localized area in a short period of time. Hot particle contamination may be present or be generated when contaminated systems are opened or when operations such as machining, cutting or grinding are performed on highly radioactive materials.

1. A hot particle is defined at Jefferson Lab as a small radioactive particle, possibly not visible to the eye, having an emission rate of at least 10,000 disintegrations per second total beta-gamma activity.
2. Measures for controlling hot particles, as identified in items 3 through 7 of this Article, should be implemented under the following conditions:
 - a. Upon identification of hot particles,
 - b. During new or non-routine operations with a high potential for hot particles, based on previous history,
 - c. Upon direction of the Radiological Control Group.
3. Areas or operations with the potential for hot particle contamination should be surveyed in accordance with [Article 553.6](#).
4. Contamination Area posting should be annotated to specifically identify the presence of hot particles.
5. Access to hot particle areas should be controlled by a job-specific RWP. The following controls should be considered for inclusion on the RWP:
 - a. Periodic personnel monitoring during the work activity, at a frequency based on the potential magnitude of skin exposure,
 - b. Additional Personal Protective Equipment and clothing,
 - c. Direct Radiological Control coverage during work or assistance during protective clothing removal,
 - d. Use of sticky pads or multiple step-off pads.
6. Personal Protective Equipment and clothing used in hot particle areas should be segregated from other radiological protective equipment and clothing during laundering and surveyed prior to reuse.
7. Response to hot particle skin contamination of personnel should include the following:
 - a. Immediate removal and retention of the hot particle for subsequent analysis,
 - b. Analysis of the particle,
 - c. Assessment of worker dose,
 - d. Evaluation of work control adequacy.



PART 5 Evaluation of Performance

During the conduct of radiological work and the handling of radioactive materials, abnormal events may occur which could indicate a weakness or area of programmatic breakdown of radiological controls. Prompt, consistent gathering of facts related to such events is required to satisfy reporting and investigation requirements and to formulate corrective actions to prevent recurrence. In addition, successful performance or completion of unique activities should be evaluated to identify and incorporate appropriate lessons learned.

Analysis of the facts should reveal areas where improvements can be made or identify methods to prevent the recurrence of undesired results.

351 Conduct of Critiques

Critiques are meetings of the personnel knowledgeable about an event (either a success or an abnormal event) to document a chronological listing of the facts. The purpose of the critique is not to assign blame, but to establish and record the facts.

1. Critiques should be conducted for successes and abnormal events.
2. Critique leaders should be trained in the required elements of the critique process and the appropriate methods of conducting and controlling the critique.
3. Critique meetings should be conducted as soon as practicable after the event or situation is stabilized, or after a successful evolution is completed. Critiques of abnormal events should be conducted preferably before involved personnel leave for the day.
4. At a minimum, the general critique process should include the following elements:
 - a. Formal meetings, chaired by a critique leader
 - b. Attendance by all who can contribute
 - c. Personal statement forms completed by selected personnel before the meeting
 - d. Attendance records and meeting minutes, reviewed and approved by the critique leader and all contributors
 - e. Personal statements, signed and attached to the meeting minutes
 - f. A listing of the facts in chronological order
 - g. Supporting materials, including documents, records, photographs, parts and logs, maintained by the critique leader.
5. Evaluation of complex evolutions or events may require multiple critiques.

352 Post-Job Reviews

Performance should be reviewed after completion of non-routine radiological work.

353 Lessons Learned

Lessons learned are available from post-job reviews and reports of past radiological events on site and at other facilities. The Radiation Control Group, in conjunction with line management, should evaluate lessons learned, provide prompt distribution, and incorporate the lessons into the Radiological Control Program, the radiological training program, and related operations. To ensure wide distribution to Jefferson Lab personnel, lessons learned should be submitted on a Notable Event Report of EH&S Manual [Appendix 5300-T3 Notable Event and Notification Procedure](#). Jefferson Lab Radiation Control Group personnel should periodically meet with other radiological professionals from other DOE accelerators to discuss lessons learned.

PART 6 Considerations for the Design and Control of Facilities

361 Design Considerations

Measures shall be taken to maintain radiation exposure in controlled areas as low as is reasonably achievable through facility and equipment design and administrative control. The primary methods used shall be physical design features (e.g., confinement, ventilation, remote handling, and shielding). Administrative controls and procedural requirements shall be employed only as supplemental methods to control radiation exposure.

1. During the design of new facilities or modification of existing facilities, the following objectives shall be adopted:
 - a. Optimization methods shall be used to assure that occupational exposure is maintained ALARA in developing and justifying facility design and physical controls.
 - b. The design objective for controlling personnel exposure to a radiological worker from external sources of radiation in areas of continuous occupational occupancy (2000 hours per year) shall be to maintain exposure levels below an average of 0.5 mrem per hour and as far below this average as is reasonably achievable. The design goal for a radiologically controlled area is such that a radiological worker will not receive a dose in excess of 250 mrem in a year.
 - c. The design objectives for exposure rates for potential exposure to a radiological worker where occupancy differs from the above shall be ALARA and shall not exceed 20 percent of the applicable standards in [Article 213](#).
2. For specific activities where use of physical design features is demonstrated to be impractical, administrative controls and procedural requirements shall be used to maintain radiation exposures ALARA.
3. The design objective for control of airborne radioactive material shall be to avoid releases to the workplace atmosphere. In the event that is not feasible, exposure to workers shall be kept ALARA through use of ventilation and confinement.
4. The design or modification of a facility and the selection of materials shall include features that facilitate operations, maintenance, decontamination, and decommissioning.

362 Control Considerations and Procedures

1. During routine operations, the combination of design features and administrative control procedures shall provide that:
 - a. The anticipated magnitude of the total effective dose equivalent shall not exceed 5 rem in a year and should not exceed 1 rem in a year.
 - b. The anticipated magnitude of the committed dose equivalent to any organ or tissue, plus any deep dose equivalent from external exposure, shall not exceed 50 rem in a year and should not exceed 2.5 rem in a year;
 - c. Exposure levels are as low as reasonably achievable.



2. The ALARA process will be utilized for personal exposures to ionizing radiation, though it will not be the standard of care.
3. Other performance goals and indicators appropriate to design and control procedures should be monitored such as:
 - a. Personal Protective Equipment requirements and practices to accommodate other hazards on the site (i.e., non-essential radiation protective equipment that potentially worsens a coincident hazard.)
 - b. Use of respiratory protection as normal conduct of operation due to lack of engineered controls and temporary nature of the work.
 - c. Monitoring and survey frequency for inactive facilities or large areas that are infrequently occupied.

363 Environmental Conditions

Inclement weather or other environmental conditions may disrupt radiological controls. If that occurs, the following actions should be considered:

1. The use of covers, wind screens and runoff collection basins to preclude the inadvertent spread of radioactive material.
2. Provisions for worksite personnel to assemble and be monitored prior to release or reestablishment of work.
3. Evaluation of work area to determine if a need exists for modified work controls or decontamination.

364 Other Workplace Hazards

Radiological controls should be implemented in a balanced way to ensure that protection from all workplace hazards can be implemented. Other hazards to consider include:

1. General construction hazards
2. Confined spaces
3. Flammable materials
4. Reactive chemicals
5. Heat stress
6. Chemical exposures
7. Energized electrical equipment
8. Biological hazards
9. Rotating equipment
10. Noise and vibration
11. Excavations
12. Restricted vision with respirator use
13. Increased stay times due to PPE

Appendix 3A: Suggested Checklist for Reducing Occupational Radiation Exposure

Preliminary Planning and Scheduling

- Plan in advance
- Delete unnecessary work
- Determine expected radiation levels
- Estimate person-rem
- Sequence jobs
- Schedule work
- Select a trained and experienced work force
- Identify and coordinate resource requirements

Preparation of Work Control Documents

- Include special radiological control requirements in technical work documents
- Perform ALARA pre-job review
- Plan access to and exit from the work area
- Provide for service lines (air, welding, ventilation)
- Provide communication (sometimes includes closed-circuit television)
- Remove or shield sources of radiation
- Plan for installation of temporary shielding
- Decontaminate
- Work in lowest radiation levels
- Perform as much work as practicable outside radiation areas
- State requirements for standard tools
- Consider special tools, including robots
- State staging requirements for materials, parts and tools
- Incorporate Radiological Control Hold Points
- Minimize discomfort of workers
- Revise estimates of person-rem
- Prepare Radiological Work Permits (RWPs)

Temporary Shielding

- Design shielding to include stress considerations
- Control installation and removal by written procedure
- Inspect after installation
- Conduct periodic radiation surveys
- Prevent damage caused by heavy lead temporary shielding
- Balance radiation exposure received in installation against exposure saved by installation
- Shield travel routes

- Shield components with abnormally high radiation levels early in the maintenance period
- Shield position occupied by worker
- Perform directional surveys to improve design of shielding by locating source of radiation
- Use mock-ups to plan temporary shielding design and installation
- Consider use of water-filled shielding

Rehearsing and Briefing

- Rehearse
- Use mock-ups duplicating working conditions
- Use photographs and videotapes
- Supervisors brief workers

Performing Work

- Comply with technical work documents and RWPs
- Post radiation levels
- Keep excess personnel out of radiation areas
- Minimize radiation exposure
- Supervisors and workers keep track of radiation exposure
- Workers assist in radiation and radioactivity measurements
- Delegate radiological control monitoring responsibilities
- Evaluate use of fewer workers
- Reevaluate reducing radiation exposures
- Compare actual collective dose against pre-job estimate
- Review work practices to see if changes will reduce dose
- Coordinate personnel at the job site to reduce nonproductive time

Post-Job Debriefing

- Review collective dose against estimate
- Review conduct of work
- Evaluate positive/negative portions of work
- Review potential changes to enhance efficiency
- Review possible conflicts of Rad Controls with general safety
- Resolve Rad Control conflicts with Industry Safety Reports
- Recommend specific changes for subsequent jobs

Appendix 3B: Physical Access Controls for High and Very High Radiation Areas

One or more of the following features shall be used for each entrance or access point to a high radiation area where radiation levels exist such that an individual could exceed a deep dose equivalent to the whole body of 1 rem in any one hour at 30 centimeters from the source or from any surface that the radiation penetrates:

1. A control device that prevents entry to the area when high radiation levels exist or upon entry causes the radiation level to be reduced below that level defining a High Radiation Area;
2. A device that functions automatically to prevent use or operation of the radiation source or field while personnel are in the area;
3. A control device that energizes a conspicuous visible or audible alarm signal so that the person entering the High Radiation Area and the supervisor of the activity are made aware of the entry;
4. Entryways that are locked, except during periods when access to the area is required, with positive control over each entry;
5. Continuous direct or electronic surveillance that is capable of preventing unauthorized entry;
6. A control device that will automatically generate audible and visual alarm signals to alert individuals in the area before use or operation of the radiation source and in sufficient time to permit evacuation of the area or activation of a secondary control device that will prevent use or operation of the source. Prior to operation of the accelerator:
 - a. An announcement indicating that a tunnel sweep will commence within a certain period of time.
 - b. A sweep (physical search) of the accelerator enclosure, which requires a sequential key-activated enabling of Run/Safe boxes. Run/Safe boxes visually indicate accelerator state and allow for emergency shut down of the accelerator.
 - c. A second announcement indicating that radiation producing activities will begin in the enclosure followed by a dimming of the enclosure lighting.
7. In addition to the above requirements, additional measures shall be implemented to ensure that individuals are not able to gain unauthorized or inadvertent access to Very High Radiation Areas.
8. Physical access controls over High and Very High Radiation Areas shall be established in such a way that does not prevent rapid evacuation of personnel.



Appendix 3C: Contamination Control Practices

Selection of Protective Clothing

1. Workers should inspect protective clothing prior to use for tears, holes or split seams that would diminish protection. All defective items should be replaced with intact protective clothing.
2. Protective clothing as prescribed by the Radiological Work Permit should be selected based on the contamination level in the work area, the anticipated work activity, worker health considerations, and regard for non-radiological hazards that may be present. [Table 3-1](#) provides general guidelines for selection. As referenced in the table, a full set and double set of protective clothing (PC) typically includes:

Full Set of PCs

- a. Coveralls
- b. Cotton glove liners
- c. Gloves
- d. Shoe covers
- e. Rubber overshoes
- f. Hood

Double Set of PCs

- a. Two pairs of coveralls
- b. Cotton glove liners
- c. Two pairs of gloves
- d. Two pairs of shoe covers
- e. Rubber overshoes
- f. Hood

3. Cotton glove liners may be worn inside standard gloves for comfort, but should not be worn alone or considered as a layer of protection.
4. Shoe covers and gloves should be sufficiently durable for the intended use. Leather or canvas work gloves should be worn in lieu of or in addition to standard gloves for work activities requiring additional strength or abrasion resistance.
5. Use of hard hats in Contaminated Areas should be controlled by the Radiological Work Permit. Hard hats designated for use in such areas should be distinctly colored or marked.
6. Shoe covers and gloves should be secured or taped at the coverall legs and sleeves when necessary to prevent worker contamination. Tape should be tabbed to permit easy removal.
7. Supplemental pocket or electronic dosimeters should be worn outside the protective clothing, in a manner accessible to the worker. Workers should protect such dosimeters from contamination by placing them in an outer coverall pocket or in plastic bags or pouches.
8. Outer personal clothing should not be worn under protective clothing for work conditions requiring a double set of protective clothing.

Removal of Protective Clothing

Potentially contaminated protective clothing should be removed without spreading contamination and in particular without contaminating the skin. Workers should be instructed not to touch the skin or place anything in the mouth during protective clothing removal. Instructions for protective clothing removal comparable to the sequence presented below should be posted adjacent to the step-off pad in accordance with [Article 325.6](#).

The RCG may alter the order of PC removal based on the specific conditions.

Sequence for Removing a Full Set of Protective Clothing at the Step-Off Pad

Before stepping out of the Contaminated Area or Airborne Radioactivity Area to the step-off pad, the worker should:

1. Remove exposed tape
2. Remove rubber overshoes
3. Remove gloves
4. Remove hood from front to rear
5. Remove respiratory protection, as applicable
6. Remove coveralls, inside out, touching inside only
7. Take down barrier closure, as applicable
8. Remove each shoe cover, placing shoe onto clean step-off pad
9. Remove cloth glove liners
10. Replace barrier closure, as applicable
11. Commence whole body monitoring
12. Monitor badge and dosimeter.

The sequence for the removal of primary and supplemental dosimetry is dependent upon where the dosimetry was worn and the potential for contamination.

Sequence for Removing a Double Set of Protective Clothing using Two Step-Off Pads

Before stepping to the inner step-off pad, the worker should:

1. Remove exposed tape
2. Remove rubber overshoes
3. Remove outer gloves
4. Remove hood from front to rear
5. Remove respiratory protection, as applicable
6. Remove outer coverall, inside out, touching inside only
7. Remove tape from inner coverall and sleeves
8. Remove each outer shoe cover, stepping on inner step-off pad as each is removed
9. Remove inner rubber gloves
10. Remove inner coveralls, inside out, touching inside only
11. Take down barrier closure, as applicable
12. Remove each inner shoe cover, placing shoe on clean outer step-off pad



13. Remove cotton glove liners
14. Replace barrier closure, as applicable
15. Commence whole body monitoring
16. Monitor badge and dosimeter

The sequence for the removal of primary and supplemental dosimetry is dependant upon where the dosimetry was worn and the potential for contamination.

Use of Multiple Step-Off Pads

1. Multiple step-off pads should be used to control exit from High Surface Contamination Areas. These pads define interim control measures within the posted area to limit the spread of contamination. The following controls apply:
 - a. The inner step-off pad should be located immediately outside the highly contaminated work area, but still within the posted area.
 - b. The worker should remove highly contaminated outer clothing prior to stepping on the inner step-off pad.
 - c. Additional secondary step-off pads, still within the posted area, may be utilized as necessary to restrict the spread of contamination out of the immediate area.
 - d. The final or outer step-off pad should be located immediately outside the Contamination Area.

Table 3-1: Guidelines for Selecting Protective Clothing (PC)

Removable Contamination Levels			
Work Activity	Low (1 To 10 Times Table 2-2 Values)	Moderate (10 To 100 Times Table 2-2 Values)	High (> 100 Times Table 2-2 Values)
Routine	Full set of PCs	Full set of PCs	Full set of PCs, double gloves, double shoe covers
Heavy work	Full set of PCs, work gloves	Double set of PCs, work gloves	Double set of PCs, work gloves
Work with pressurized or large volume liquids, closed system breach	Full set of non-permeable PCs	Double set of PCs (outer set non-permeable), rubber boots	Double set of PCs and non-permeable outer clothing, rubber boots

Note:

For hands-off tours or inspections in areas with removable contamination levels 1 to 10 times the values in Table 2-2, combinations of lab coats, shoe covers and gloves may be used instead of full PCs.

Appendix 3D: Guidelines for Personnel Monitoring with Hand-Held Survey Instruments

General Requirements

1. Verify that the instrument is in service, set to the proper scale, and the audio output can be heard during monitoring.
2. Hold the probe less than 1/2 inch from surface being surveyed for beta and gamma contamination and approximately 1/4 inch for alpha contamination.
3. Move the probe slowly over surface, approximately 2 inches per second.
4. If the count rate increases during monitoring, pause for 5 to 10 seconds over the area to provide adequate time for instrument response.
5. If the count rate increases to a value greater than a pre-established contamination limit or the instrument alarms, remain in the area and notify Radiological Control personnel.
6. The whole body monitor should take at least two to three minutes.

Performance of Monitoring:

1. Monitor the hands before picking up the probe.
2. Monitor in the following order:
 - a. Head (pause at mouth and nose for approximately 5 seconds)
 - b. Neck and shoulders
 - c. Arms (pause at each elbow)
 - d. Chest and abdomen
 - e. Back, hips and seat of pants
 - f. Legs (pause at each knee)
 - g. Shoe tops
 - h. Shoe bottoms (pause at sole and heel)
 - i. Personnel and supplemental dosimeters.
3. Return the probe to its holder and leave the area. The probe should be placed on the side or face up to allow the next person to monitor their hands before handling the probe.



Chapter 4: Radioactive Materials and Sources

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REFERENCES:

The following reference documents are used for guidance regarding this chapter. The CFR web site <http://www.gpoaccess.gov/cfr/index.html> contains further information on this reference material.

ANSI/UL 586 provides HEPA filter integrity testing criteria.

Resource Conservation and Recovery Act and Toxic Substances Control Act applies to waste that contains both radioactive and hazardous materials.

49 CFR 170 through 180 describe requirements for inspecting and surveying packages, containers and transport conveyances prior to off-site transport.

10 CFR 835



PART 1 Radioactive Material Identification, Storage and Control

For the purposes of this Manual, radioactive material is any material, equipment, or system component, determined to be contaminated or emit radiation above [Table 2-2](#) values or 20 $\mu\text{rem/hr}$ on contact. Items located where activating sources may be found or in areas that may result in contamination shall be considered radioactive materials until determined otherwise. Radioactive material includes volume-activated material, contaminated material, sealed and unsealed sources, and any other materials that emit radiation. Temporary sources of radiation as described in [Part 4](#) of this Chapter are not considered to be radioactive materials.

411 Requirements

1. Materials in Contamination, High Contamination or Airborne Radioactivity Areas or located within an Experimental Hall or Accelerator unless otherwise specifically stated in an RWP (e.g., the Experimental Hall B exception in the general access RWP), shall be considered radioactive material until surveyed and released. These survey and release requirements do not apply to Airborne Radioactivity Areas where only gaseous, short-lived (half-life of 1 hour or less) activation products are present.
2. Except for sealed and unsealed sources, radioactive materials located within Contamination, High Contamination or Airborne Radioactivity Areas or installed in the beamline do not require specific labeling or packaging.

412 Labeling of Radioactive Materials

1. Each item or container of radioactive material shall bear a durable, clearly visible label bearing the standard radiation warning trefoil and the words "Caution, Radioactive Material" or "Danger, Radioactive Material." The label shall also provide sufficient information to permit individuals handling, using, or working in the vicinity of the items or containers, to take precautions to avoid or control exposures.
2. Exceptions to labeling requirements.
 - a. Items and containers may be excepted from the radioactive material labeling requirements of Article 412.1 when:
 - (1) Used, handled, or stored in areas posted and controlled in accordance with this chapter and sufficient information is provided to permit individuals to take precautions to avoid or control exposures; or
 - (2) The quantity of radioactive material is less than one tenth of the values specified in [Appendix 2E](#); or
 - (3) Packaged, labeled, and marked in accordance with the regulations of the Department of Transportation or DOE Orders governing radioactive material transportation; or
 - (4) Inaccessible, or accessible only to individuals authorized to handle or use them, or to work in the vicinity; or
 - (5) Installed in manufacturing, process, or other equipment, such as piping, tanks, and accelerator beamline components.
 - b. Radioactive material labels applied to sealed radioactive sources may be excepted from the color specifications of Article 412.3.



3. Labels shall have a yellow background with a black or magenta standard radiation symbol. Lettering shall be black or magenta. Magenta is preferred.
4. Labels should include contact radiation levels, removable surface contamination levels (specified as alpha or beta-gamma), dates surveyed, surveyor's name and description of items.
5. Packaged radioactive material should have the label visible through the package or affixed to the outside.
6. Radioactive Material Forms, Tags and Labels shall only be removed when authorized by a member of the RCG. If survey data or component installation indicates that activated material should no longer be classified as such, an RCG staff member should be contacted to re-survey the item, remove tracking forms and labels and release the item. If an activated component is reinstalled, an RCG staff member should be contacted to remove the tracking forms, tags and labels as appropriate. In addition, any radiation signs, tags, or labels to be treated as waste shall be defaced or rendered unintelligible.

413 Activated Materials Surveys

1. Materials and equipment can become radioactive when exposed to the beam or radiation generated by beam interaction. Components removed from the beam line are required to be surveyed and labeled as appropriate. Any material stored in an accelerator enclosure or attached to the beam line shall be surveyed prior to removal from the accelerator enclosure unless excepted by the RCG. If determined to be activated, the RCG shall assign a custodian. It is the responsibility of the custodian to ensure the use and storage of these materials is in compliance with applicable Federal regulations and Jefferson Lab procedures.
2. Materials surveyed and determined to be non-radioactive may be stored or handled on the Jefferson Lab site. Radioactive materials shall not be removed from the site without concurrence of the RCG.

414 Tracking of Radioactive and Activated Material

1. Radioactive materials movement shall be controlled as specified in applicable procedures.
2. All radioactive material (including He-3 tanks, because of the inherent 3H contamination) brought onto the Jefferson Lab site shall be subject to the policies and controls as specified in this Supplement and applicable procedures. At the discretion of the RCG, activated material (re)installed as an accelerator component may no longer require tracking as activated material. Systems containing He-3 require tracking by the RCG whether installed or not.

415 Radioactive Material Packaging

1. Radioactive material that is confirmed or suspected of having removable radioactive contamination levels greater than [Table 2-2](#) values, shall be securely wrapped (e.g., in plastic) or placed in a container.
2. Radioactive material with sharp edges or projections should be taped or additionally protected to ensure package integrity.



3. Radioactive material with removable or potentially removable contamination levels in excess of 100 times [Table 2-2](#) values should have additional packaging controls such as double-wrapping or the use of plastic bags inside containers.
4. Yellow plastic wrapping material should be used for packaging radioactive material. Yellow plastic sheets or bags should not be used for non-radiological purposes.
5. The amount of combustible material used in packaging should be minimized.

416 Radioactive Material Storage

This article applies to the storage of non-source radioactive materials. Radioactive sources are discussed in [Part 3](#) of this chapter.

1. Radioactive materials shall be stored in locations approved by the RCG.
2. The dose rate on the outside of containers containing radioactive materials shall be commensurate with the levels allowed in the area where the container is located, and should not contribute greatly to the area's background level. Should the container adjoin any area whose classification is less than that of the area in which it is located, a radiation survey shall be performed in the adjoining area to ensure that there is no need to upgrade its classification. Special attention shall be paid to situations where the container adjoins the exterior wall of a building so that exposure rates outside the building are less than 50 $\mu\text{rem/hr}$.
3. Good practice indicates that a radiation survey of the exterior of the container should be performed any time an object is added to or removed from the container or the contents are shifted. A review of labeling, shielding, etc., should be performed based on the new results.
4. Containers of radioactive materials shall be marked with signs indicating that radioactive material is stored within. The exposure rate of the object having the highest exposure rate should be recorded along with a list of contents in the container. Contact dose rate on the surface of the container should be recorded.
5. General Rules and Recommendations
 - a. Radioactive material shall be stored in a designated Radioactive Material Area when not in use.
 - b. Decontamination or disposal of radioactive material is the preferred alternative to long-term storage.
 - c. The Radiation Control Manager shall approve each Radioactive Material Area to be used continuously for a period of greater than six months. Radioactive Material Areas for transient conditions such as during equipment maintenance may be established by a qualified Radiological Control Technologist.
 - d. Storage of non-radioactive material in a Radioactive Material Area is discouraged.
 - e. Outdoor storage of radioactive material is discouraged. In cases where outdoor storage is necessary, the integrity of any containers used shall be ensured to prevent degradation from weathering and subsequent release of radioactive material. A container is defined as any device used to prevent degradation from weathering and subsequent release of radioactive material. The custodian should check container integrity monthly at outdoor Radioactive Material Areas.



- f. Radioactive material should be stored in a manner that reduces combustible loading. The use of cardboard containers for storage is discouraged.
- g. Flammable or combustible materials should not be stored adjacent to Radioactive Material Areas.
- h. Fire protection measures, such as smoke detectors, water sprinklers and fire extinguishers, shall be considered when establishing a Radioactive Material Area.
- i. Installation or storage of Helium-3 tanks or containers within the experimental halls shall be limited to a tritium (H-3) contamination limit of 10 mCi per experimental hall. This limit may only be exceeded through expressed written consent by the RadCon Manager (e.g., per RWP).

417 Accountability

Each custodian is responsible for the proper handling and storage of radioactive material under his/her cognizance. The custodian shall ensure that a current list of all radioactive materials and their storage areas is provided to the RCG whenever requested.

The RCG shall perform periodic audits of the radioactive material tracking and inventory system. This is normally done by conducting a physical inventory of radioactive material in selected areas on a routine basis. These inventories should be performed at least semi-annually.



PART 2 Release and Transportation of Radioactive Material

421 Release to Uncontrolled Areas

1. Potentially radioactive material in RCAs or Radioactive Material Areas shall be surveyed prior to release to uncontrolled areas. Documentation of this evaluation shall be maintained.
2. Potentially radioactive material being released to uncontrolled areas should be evaluated for contamination under any coatings. Process knowledge should be applied to this evaluation.
3. Material not immediately released after survey shall be controlled to prevent contamination/activation while awaiting release.
4. Labels shall be removed or defaced prior to release of material for unrestricted use.

422 Transportation of Radioactive Material

1. The 49 CFR 173 contamination values shall be used as controlling limits for transportation off-site. These limits also apply to on-site transfers of shipments by non-DOE conveyances received from or destined to off-site locations.
2. [Table 2-2](#) removable contamination values shall be used as controlling limits for on-site transportation.
3. On-site transfers over nonpublic thoroughfares or between Jefferson Lab facilities shall be performed in accordance with all applicable written procedures.
4. On-site transfers over public thoroughfares shall be performed or directed by the RCG and shall be in accordance with Department of Transportation, state and local shipping requirements and pre-approved agreements.
5. Off-site shipments of radioactive material, including subcontractors' handling of off-site shipments, shall be performed or directed by the RCG and shall be controlled and conducted in accordance with this Manual and applicable Federal, state and local regulations.
6. All shipping and receiving of radioactive materials shall be done according to applicable Jefferson Lab procedures.
7. The site emergency plan describes appropriate responses for potential on-site radioactive material transportation accidents.

PART 3 Radioactive Source Controls

431 Definitions

1. A radioactive source is radioactive material of known type and activity in solid, liquid, or gaseous form for use in activities such as instrument calibration, instrument response testing, experiments, etc.
2. A sealed source is a radioactive source manufactured, obtained, or retained for the purpose of utilizing the emitted radiation. The sealed source consists of a known or estimated quantity of radioactive material contained within a sealed capsule, sealed between layer(s) of non-radioactive material, or firmly fixed to a non-radioactive surface by electroplating or other means.
3. An unsealed source is radioactive material that may be contacted or dispersed under normal conditions of use. Examples of unsealed sources are liquid sources and reactor fuel elements.

432 Procurement, Receipt, and Shipment of Sources

1. All sources of radioactive material and He-3 (due to the inherent risk of H-3 contamination) shall be procured through the Radiation Control Group. Persons needing sources are to arrange for procurement through the RCG. If the required source is available on the Jefferson Lab site, the RCG may arrange its loan to the requestor, otherwise the RCG will approve its purchase if necessary.
2. All radioactive sources being sent to the Jefferson Lab site must be received by the RCG. The Radiation Control Group shall perform receipt surveys of radiological material shipments.
3. He-3 containers shall be verified to contain less than 10 mCi of H-3 contamination by analyzing a sample of the container's contents, verifying sample records of previous He-3 containers received from the manufacturer, or reviewing manufacturer's certification of the container's H-3 content. For example, glass cells filled with high purity He-3 used as polarized targets in the experimental halls have been granted a blanket exemption from Radiation Control Group tracking and controls based on manufacturer purity specifications.
4. Receipt of packages containing radioactive material.
 - a. If packages containing quantities of radioactive material in excess of a Type A quantity (as defined at 10 CFR 71.4) are expected to be received from radioactive material transportation, arrangements shall be made to either:
 - (1) Take possession of the package when the carrier offers it for delivery; or
 - (2) Receive notification as soon as practicable after arrival of the package at the carrier's terminal and to take possession of the package expeditiously after receiving such notification.
 - b. Upon receipt from radioactive material transportation, external surfaces of packages known to contain radioactive material shall be monitored if the package:
 - (1) Is labeled with a Radioactive White I, Yellow II, or Yellow III label (as specified at 49 CFR 172.403 and 172.436-440); or
 - (2) Has been transported as low specific activity material (as defined at 10 CFR 71.4) on an exclusive use vehicle (as defined at 10 CFR 71.4); or
 - (3) Has evidence of degradation, such as packages that are crushed, wet, or damaged.



- c. The monitoring required by paragraph (b) of this section shall include:
 - (1) Measurements of removable contamination levels, unless the package contains only special form (as defined at 10 CFR 71.4) or gaseous radioactive material; and
 - (2) Measurements of the radiation levels, unless the package contains less than a Type A quantity (as defined at 10 CFR 71.4) of radioactive material.
- d. The monitoring required by paragraph (b) of this section shall be completed as soon as practicable following receipt of the package, but not later than 8 hours after the beginning of the working day following receipt of the package.
5. Upon receipt of the source, the RCG shall assign each source a Jefferson Lab serial number, enter it into the source inventory tracking system, and tag the source with its serial number and isotopic content. Radiation type, dose rate on contact, activity and date of determination, and half life shall be included in the corresponding inventory record in the source inventory tracking system.
6. Persons wishing to bring a radioactive source onto the Jefferson Lab site shall notify the RCG in writing well in advance of the transfer of the source so that proper provision can be made for its care and custody.
7. All radioactive sources being sent off the Jefferson Lab site shall be processed through the RCG. The RCG shall ensure that the source is properly packaged and United States Department of Transportation (DOT) regulations are met.

433 Movement and Use of Sources

1. Sealed radioactive sources shall be used, handled, and stored in a manner commensurate with the hazards associated with operations involving the sources. All persons using sources shall receive documented instruction on their proper storage and use.
2. Radioactive sources shall not be permanently moved from their designated storage locations or moved from one building to another without the prior approval of the RCG. When radioactive sources are stored temporarily outside of their approved storage location or are used in an experimental setup, a Radioactive Material Tracking Form shall be posted in plain view near the source. The Source Custodian can initiate this form and request a form serial number and survey associated with the experimental setup or temporary storage location.
3. Sources shall be used according to approved written instructions or work permits. Radiation warning signs must be posted as specified in Articles [232](#), [233](#) and [234](#) in plain view at the location of the source. Additional posting near the accesses to the area in which the source is being used may also be required. If necessary, a suitable "controlled area" personnel barrier must be erected to prevent access by unmonitored personnel. Instructions for safe use of the source, RCOPs or radiation work permits should be placed in the source log book. Persons handling sources are required to be Jefferson Lab trained radiation workers.
4. Use of some sources may require the completion of an RCOP. Consult the RCG for further information.



434 Custody of Sources

1. An individual (called the Source Custodian) shall be assigned the functional responsibility for each source. The Source Custodian is responsible for the care, location, condition, and proper use of each source in his/her custody. The Source Custodian shall verify by signature that the duties as custodian are understood.
2. Source Custodians must be employees of Jefferson Lab. They shall retain responsibility for each source in their custody until formally relieved by the RCG, a person approved by the RCG, or another Source Custodian.
3. In the case of guests requiring use of sources brought with them, the Jefferson Lab host shall secure an agreement with a custodian for storage and use of the source.
4. The Source Custodian is responsible for notifying the RCG in the event the source suffers any damage that could possibly result in loose contamination or it is mislaid or lost. Such notification should be performed as promptly as possible. The RCG will determine what notifications are necessary and will make the proper reports.
5. Source Custodians shall be Radiation Worker I trained at a minimum.
6. Source Custodians can take preliminary radiation surveys to verify that sources are properly stored or installed in an experimental setup. These surveys are required to be verified by RCG Staff surveys.
7. Source Custodians may remove Radioactive Material Area or Radiologically Controlled Area signs if conditions no longer require their posting. Reusable signs or labels should be stored in the source locker when not in use.

435 Storage of Sources

1. Each Source Custodian shall provide a container for storing sources when not in use. The container should be approved by the RCG prior to its use and shall as a minimum meet the following criteria:
 - a. used only for the storage of radioactive material
 - b. able to be securely locked, copy of key provided to RCG for audit
 - c. posted with radiation and radioactive material warning signs as appropriate
 - d. sturdily constructed and shielded so that the dose rate at 30 cm from the exterior is less than 50 μ rem/hr.
2. Sources that are required to be permanently attached to an instrument must be securely attached or embedded within the structure of the instrument. Such an instrument must bear a notice stating that it contains a radioactive source and the serial number of the source.
3. Sources meeting the definition of an accountable sealed source per the definition of 10 CFR 835 shall be maintained in locked storage when not in use, and shall be attended at all times when in use unless secured against unauthorized removal.



436 Records and Inspections

1. Source Control Log Sheets or electronic records, records of source inventory, leak test, and Source Custodian training, National Institute on Standards and Technology (NIST) traceability certificates, and approved Source Request Forms shall be kept at the Radiological Control Office.
2. The Source Custodian shall maintain a source utilization log at the source storage location for each source in his/her custody. The log shall bear a full description of the source:
 - a. Set of instructions for safe use, copy of RCOP or radiation work permit
 - b. Jefferson Lab serial number
 - c. Isotope and activity
 - d. Any special instructions for handling, name of custodian, current location
3. Labels used to identify sealed sources shall meet the requirements of [Article 412](#) and shall also identify the radionuclide, activity, date of assay, and serial number.
4. Each time the source is removed for use, an entry is to be made in the logbook (or registered electronically in the storage equipment (e.g., prox card reader.)) The log shall be located where the source is normally stored and shall be readily available for use or inspection.
5. Additional records or reports or documentation concerning use of, tampering or loss of sources shall be maintained at the RCG.

PART 4 Radiation Generating Device Controls

441 Definition

A radiation generating device (RGD) is a device which produces ionizing radiation, including certain sealed sources, small particle accelerators used for single purpose applications which produce ionizing radiation (e.g., radiography), and electron generating devices that produce X-rays incidentally. An example of an RGD is an X-ray machine. Test stands and other RGD equipment may be exempted from these requirements at the discretion of the RCG if other controls provide equivalent safety and accountability.

442 Custody and Storage

1. Each RGD will be issued a Jefferson Lab serial number. A Source Control Log Book detailing source use shall be kept up to date with applicable information. The RGD must have an assigned custodian who will be primarily responsible for its safe operation.
2. A representative of the RCG must approve the location of each RGD prior to its operation. This pertains not only to the initial location but also to any subsequent locations.
3. The duties and responsibilities of the assigned custodian are the same as those of the custodian of a radioactive source (see Articles [434-436](#)).
4. The use of all RGDs will require the use of an RCG approved procedure (either OSP or RCOP). Each operator of an RGD shall be a radiation worker. Consult the RCG for further information.

443 Inspection

Every six months a representative of the RCG should verify the location of each RGD and survey the location to ensure that no hazard from direct leakage of radiation occurs. Additionally, interlock and applicable safety system checks should be performed.

444 Documentation

Records of inspections shall be made and maintained.



PART 5 Source Accountability and Leak Testing

451 Inventory

An inventory of accountable radioactive sources shall be done at intervals not to exceed six months. This inventory should include non-accountable radioactive sources.

1. A representative of the Radiation Control Group shall, with the assistance of the Source Custodian if needed, locate each source and verify that the serial number is legible and evaluate the physical condition of the source, and verify the presence and adequacy of associated postings and labels.
2. An examination of the source's storage facility will be made to ensure that the source can be properly stored.
3. The electronic or paper inventory tracking system for each source should be updated to reflect the inventory.
4. Inventory of stored sources may be conducted by means of verification of storage device integrity if an auditable means is used to restrict storage device access, and it can be confirmed that the container has not been accessed or tampered with since the last inventory.
5. At the completion of the inventory, a written report including the findings of the inventory and any recommendations shall be submitted to the Radiation Control Manager.

452 Leak Testing

Leak testing of sources shall be performed during each inventory.

1. Except for sealed radioactive sources consisting solely of gaseous radioactive material or tritium, each accountable sealed radioactive source shall be subject to a source leak test upon receipt, when damage is suspected, and at intervals not to exceed six months. Source leak tests shall be capable of detecting radioactive material leakage equal to or exceeding 0.005 microcuries.
2. Notwithstanding the requirements of Article 452.1, an accountable sealed radioactive source is not subject to periodic source leak testing if that source has been removed from service. Such sources shall be stored in a controlled location, subject to periodic inventory as required by Article 452.1, and subject to source leak testing prior to being returned to service.
3. Notwithstanding the requirements of Articles 452.1 and 452.2, an accountable sealed radioactive source is not subject to periodic inventory and source leak testing if that source is located in an area that is unsafe for human entry or otherwise inaccessible.



4. The RCG shall determine the requirements for leak testing unsealed sources on a case by case basis.
5. For sources that are mounted inside an enclosure, the leak test may be performed by wiping the outside of the enclosure -- paying special attention to areas through which contamination may escape (i.e., joints, seams, etc.).
6. The leak test section of the electronic or paper inventory tracking record shall be completed to show that the source has been leak tested.
7. A representative of the RCG shall perform the leak test unless the Source Custodian is assigned that responsibility in a technical procedure.

453 Missing Sources

If, at any time, a source can not be located, the Radiation Control Manager shall be notified immediately and shall institute a search for the missing source according to applicable procedures.

454 Leaking Sources

If a source is suspected to be leaking, or is found to be leaking (as specified in source swipe or leak test procedure), it shall be controlled in a manner that minimizes the spread of radioactive contamination. The Radiation Control Group Manager shall be notified immediately. The area in which the source was stored and/or used shall be surveyed for loose contamination and decontaminated as necessary.

The RCG shall assume custody of any leaking sources and will dispose of them properly.

455 Documentation

Records of leak tests, inspections or reports shall be maintained. Documentation of loss of sealed sources including circumstance in which the sealed source was lost, and detailed efforts to locate the source should be documented in a Radiation Safety Deviation Report.

PART 6 Radioactive Waste Management

461 Introduction

All radioactive material, which is not needed for present or probable future use and which cannot be economically stored for decay, should be disposed of as radioactive waste. Compactable radioactive waste such as disposable protective clothing, rags, and compressible items should be placed in yellow radioactive waste bags. Normally, non-compactable solid and liquid radioactive waste should be placed in approved containers provided by the RCG. Large items that are suitable for "contact burial" may be disposed of without containment. Compactable and non-compactable waste should be kept separate to allow maximum efficiency in the radioactive waste disposal program.

462 Solid Non-Compactable Waste and Liquid Waste

Containers used for radioactive waste shall be approved by the RCG. An RCG representative, prior to delivery to specific areas, shall affix radioactive waste identification labels to containers as needed. Contact the RCG to arrange for transfer of containers for processing.

If items are too large for containers, the RCG should be contacted to determine what method of disposal should be used.

463 Compactable Waste

All compactable waste should be put into yellow bags that are designated by the RCG for this purpose.

The bags should not contain any of the following:

1. Metal or wood
2. Glass in any form
3. Cable over 12" long
4. Dirt, sand, sweeping compound or wet material

Contact the RCG to arrange for transfer of containers for processing.

464 Waste Minimization

The following practices should be instituted to support waste minimization.

1. Restrict quantities of hazardous materials, such as paints, solvents, chemicals, cleaners and fuels, in areas where they may be activated and take measures to prevent inadvertent radioactive contamination of these materials.
2. Reusable and recyclable materials are preferable to disposable materials.
3. Select consumable materials such as protective coverings and clothing that are compatible with waste-processing systems, volume reduction and waste form acceptance criteria.
4. Segregate known uncontaminated from potentially contaminated waste.
5. Minimize the number and size of Radioactive Material Areas.
6. Emphasize waste reduction philosophies, techniques and improved methods in training and work control documents.



465 Mixed Waste

1. Technical and administrative controls should be used to minimize the volume of mixed waste generated and the amount of radioactivity in such waste. Volume reduction methods include process optimization, materials substitution and new technology development.
2. Materials suspected of being mixed waste should be identified and segregated as soon as practical in the generating process to avoid combining mixed waste with other waste forms.

The most stringent regulatory requirements for the types of waste present should be applied to waste classification and disposal.



PART 7 Control of Radioactive Liquids and Airborne Radioactivity

471 Minimization and Control of Radioactive Liquid Wastes

1. Minimization will include evaluating operational requirements to reduce liquid production and maximize recycling activities.
2. A water management program is maintained to identify, trend and eliminate unnecessary sources of radioactive liquid waste.
3. Radioactive liquid waste is managed by permitted discharge. Systems are in place to ensure the liquid is analyzed prior to release, monitored during release and the release terminated before exceeding predetermined EPA, DOE, federal, state, or local limits.
4. Radioactive liquid waste that cannot be discharged should be processed for solidification or volume reduction prior to final disposition. This is usually accomplished by the radioactive waste disposal vendor/broker.

472 Control of Airborne Radioactivity

1. Processes and activities with the potential for producing airborne radioactivity shall include engineered controls to limit releases.
2. The Radiation Control Group shall be notified when engineered controls that prevent worker exposure to airborne radioactivity, such as barriers, containments, gloveboxes and glovebags, are compromised. An evaluation shall be made of continuing operations with compromised engineered controls. The use of respiratory protection to continue should be avoided. Implementation of short-term engineered modifications that provide a commensurate level of worker protection is the preferred alternative.

Preventive maintenance and surveillance shall be performed as described by applicable procedures to ensure equipment controls are maintained in an operable condition for containment of airborne radioactivity.

PART 8 Support Activities

481 Personal Protective Equipment

1. Protective clothing designated for radiological control use should be specifically identified by color, symbol or appropriate labeling.
2. Protective clothing designated for radiological control use should not be used for non-radiological work.
3. Personal Protective Equipment and clothing should not be stored with personal street clothing.
4. Reusable personal protective equipment shall be surveyed for contamination prior to reissue.

482 Decontamination

1. Radiological Work Permits or other work control documents shall include provisions to control contamination at the source to minimize the amount of decontamination needed.
2. Work preplanning shall include consideration of the handling, temporary storage and decontamination of materials, tools and equipment.
3. Decontamination activities should be controlled to prevent the spread of contamination.
4. Water and steam are the preferred decontamination agents. Other cleaning agents should be selected based upon their effectiveness, hazardous properties, amount of waste generated, and ease of disposal.
5. Decontamination methods should be used to reduce the number of contaminated areas.
6. Efforts should be made to reduce the level and size of contaminated areas.

483 Vacuum Cleaners and Portable Air-Handling Equipment

Improper use of vacuum cleaners and portable air-handling equipment may result in the generation of airborne radioactivity, loose surface contamination or high dose rates.

1. Vacuum cleaners and portable air-handling equipment used to control contamination or to prevent airborne radioactivity shall be equipped with High-Efficiency Particulate Air (HEPA) filters.
2. Vacuum cleaner and portable air-handling equipment HEPA filters should be integrity tested prior to initial use, when units have been opened such that the integrity of the seal around the HEPA may have been breached, dropped or mishandled and annually.
3. Vacuum cleaners used for radiological work should be:
 - a. Uniquely marked and labeled
 - b. Controlled to prevent unauthorized use
 - c. Designed to ensure HEPA filter integrity under conditions of use
 - d. Designed to prevent unauthorized or accidental access to the inner surfaces of the vacuum.
4. Airborne radioactivity levels shall be monitored when a vacuum cleaner is used in a High Contamination Area.



Chapter 5: Radiological Health Support Operations

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REFERENCES:

The following reference documents are used for guidance regarding this chapter. The CFR web site <http://www.gpoaccess.gov/cfr/index.html> contains further information on this reference material.

- ANSI N323
- DOE/EH 0026, 0027
- ANSI N42.17A - 1989
- 10 CFR 835

PART 1 External Dosimetry

511 Types of Personnel Dosimetry

At Jefferson Lab, monitoring of personnel exposed to ionizing radiation is accomplished by use of personal dosimetry devices. The four types currently in use are:

- 1) thermoluminescent dosimeters (TLD),
- 2) self reading pocket dosimeters (SRPD),
- 3) track-etch dosimeters, and
- 4) digital dosimeters.

1. Personnel monitoring TLDs are provided and processed by an outside lab and are changed semiannually. Individuals who receive more than 120 mrem during a monitoring period as determined by TLD or SRPD will be placed on a more frequent TLD processing cycle – normally monthly. Individual exposures are reviewed after each semi-annual period to make appropriate adjustments to processing frequency. The RCM may designate individuals for monthly processing at his/her discretion based on dose history, nature and location of work, and expected exposure levels for upcoming periods. TLDs are available through the RCG. Personnel external dosimetry programs shall be adequate to demonstrate compliance with the occupational exposure limits in Chapter 2, Part 1 of this Manual including routine dosimeter calibration and conformance with the requirements of the DOE Laboratory Accreditation Program for Personnel Dosimetry or has been determined by the Secretarial Officer responsible for environment, safety, and health matters to have substantially equivalent performance.

Currently, Jefferson Lab uses dosimeters that contain TLDs sensitive to gamma radiation and neutron radiation and also neutron sensitive track-etch dosimeters for individuals likely to receive detectable neutron exposure under normal operating conditions (i.e., RCG members using the AmBe instrument calibration sources). The TLDs provide dose of record for gamma rays, neutrons, x-rays and charged particle exposures. The neutron sensitive track-etch dosimeters provide secondary dose information for neutron exposure.

2. SRPDs are made in several ranges so care must be taken to obtain a dosimeter with the correct range. The dosimeter is read by the user, but must be reset by an RCG representative or an individual specifically trained to do so. SRPDs include pocket ion chambers or neutron bubble dosimeters. SRPDs are available at the RadCon building.
3. The digital dosimeter has preset alarm levels to alert the wearer when total dose approaches a limit. This type of dosimeter is available through the RCG. The digital dosimeter is not to be worn in areas where there is the possibility of encountering pulsed radiation fields.



512 Requirements

1. Appropriate dosimeters shall be worn when entering a radiologically controlled area; or where the radiation worker has the potential of exceeding 100 mrem in one year whole body dose equivalent or an annual dose to the extremities, lens of the eye, or skin greater than the Jefferson Lab Alert Levels. Neutron dosimetry shall be provided when an individual is likely to exceed 100 mrem annually from neutrons. For monitored radiological workers, the minimum requirement for these cases is the device specified by the RCG, which meets the performance requirements of DOELAP.
2. General employees, minors, declared pregnant workers, and members of the public shall wear dosimeters when they have the potential for exceeding 50 mrem in one year while on the Jefferson Lab site.
3. A TLD and SRPD or digital dosimeter shall be worn for entry into a posted high radiation or higher category area, when there is a potential of being exposed to a radiation field of 100 mrem/hr or greater, or as required by any work permit or technical work procedure.
4. Dosimeters shall be worn between the neck and waist unless otherwise specified by the Radiation Control Group. When a SRPD or digital dosimeter is worn with a TLD, the dosimeters are to be placed next to each other. The dosimeter should be worn consistently at the same location on the body unless otherwise instructed by the RCG. It should be worn on the outside of all clothing.
5. Dosimeters shall be returned to their appropriate storage location at the end of the work day. TLD badges shall be stored in the designated badge rack, and SRPDs shall be logged in by trained personnel and stored for reuse.
6. The Radiation Control Group determines the need for special configuration dosimetry. Special configuration dosimeters (rings, bracelets, etc.) are available from the RCG. A lead time of approximately 72 hours should be anticipated if a special configuration is required.
7. Personnel whose duties make them radiation workers shall request permanent dosimetry. A permanent dosimeter at Jefferson Lab is a thermoluminescent dosimeter (TLD). The person shall complete the Jefferson Lab TLD Badge Request and an Ionizing Radiation Record Transfer Request (if applicable). The Department Head and Line Manager shall sign the form to indicate that the person needs a TLD. The form(s) shall then be presented to an RCG representative who shall issue the TLD. The individual shall be limited to 100 mrem annual effective dose equivalent until all Record Transfer Requests have been returned to the RCG and a medical exam has been completed. The supervisor is directly responsible for ensuring that the worker does not exceed this limit.
8. Dosimeters shall be issued only to personnel formally instructed in their use and shall be worn only by those to whom the dosimeters were issued.
9. Part of the successfulness of an organization's efforts to reduce total exposure is ensuring that as few persons as possible are authorized to receive radiation exposure. Periodically, a review shall be performed to confirm that all persons so authorized actually have a need to be so authorized. If a person's job duties are judged to be of such a nature that they do not need to be designated as a radiation worker, he/she shall be notified by memo and be given an opportunity to present facts that he/she feels may have been overlooked. The RCG, in conjunction with the supervisor of the person concerned, shall re-evaluate the circumstances and make a final decision. The person shall be notified of the decision before any action is taken.

10. Personnel shall return dosimeters for processing as scheduled or upon request.
11. A person whose dosimeter is lost, damaged, or contaminated while working should place work in a safe condition, immediately exit the area and report the occurrence to the Radiation Control Group.

513 Circumstances Requiring an Exposure Investigation

An exposure investigation is required in the following circumstances:

1. Missing exposure record (i.e., TLD is lost or damaged).
2. Suspected inaccuracy in the exposure record. If there is a serious discrepancy between the TLD report and the person's expected exposure, the dosimetry records shall be reviewed and adjusted if necessary. Other circumstances of suspected inaccuracies requiring exposure investigations include discrepancies between multiple badges (when they are worn at the same time), exposures occurring when the person was not wearing a badge, and in accidental exposure in the beam enclosure.
3. Unusual exposures or large increase in reported exposure for a TLD badge period as compared to previous exposures.
4. Any individual exceeding the administrative alert level.

514 SRPD and Digital Dosimeters

SRPD and digital dosimeters are supplemental dosimeters that provide real-time indication of exposure to radiation and assist in maintaining personnel doses less than Administrative Control Levels. The digital dosimeter is not to be worn in areas where there is the possibility of encountering pulsed radiation fields, high magnetic fields, or radio frequency.

1. Supplemental dosimeters shall be read periodically while in use and should be exchanged (or re-zeroed by the RCG) when they reach 75 percent of full scale.
2. Routine work on a Radiological Work Permit shall be stopped when supplemental dosimeter readings indicate total exposure or rate of exposure substantially greater than planned. The Radiation Control Group shall be consulted prior to continuation of work.
3. The energy and pulse rate dependence of supplemental dosimeters should be considered in determining their applicability.

515 Area Monitoring Dosimeters

Establishment and maintenance of a comprehensive area monitoring program minimizes the number of areas requiring the issuance of personnel dosimeters and demonstrates that doses inside Controlled Areas are negligible. Minimizing the number of personnel dosimeters issued saves in the costs of operating the dosimetry program and reduces costs associated with maintaining personnel with enhanced training and qualifications.

Area monitoring dosimeters should be used to record and document radiation levels in routinely occupied areas adjacent to areas where radiation or operations with radiation exist.

PART 2 Internal Dosimetry

521 Individual Monitoring

1. For the purpose of monitoring individual exposures to internal radiation, internal dosimetry programs (including routine bioassay programs) shall be conducted for:
 - a. Radiological workers who, under typical conditions, are likely to receive a committed effective dose equivalent of 0.1 rem (0.001 sievert) or more from all occupational radionuclide intakes in a year;
 - b. Declared pregnant workers likely to receive an intake or intakes resulting in a dose equivalent to the embryo/fetus in excess of 10 percent of the limit stated in [Article 216](#);
 - c. Occupationally exposed minors who are likely to receive a dose in excess of 50 percent of the applicable limit stated in [Article 214](#) from all radionuclide intakes in a year; or
 - d. Members of the public entering a controlled area likely to receive a dose in excess of 50 percent of the limit stated in [Article 215](#) from all radionuclide intakes in a year.

2. Internal dose monitoring programs implemented to demonstrate compliance with [Chapter 2](#) of this manual shall be adequate to demonstrate compliance with the dose limits established in Tables [2-1A](#) and [2-1B](#) and (if applicable) shall be:
 - a. Accredited, or excepted from accreditation, in accordance with the DOE Laboratory Accreditation Program for Radiobioassay; or
 - b. Determined by the Secretarial Officer responsible for environment, safety and health matters to have performance substantially equivalent to that of programs accredited under the DOE Laboratory Accreditation Program for Radiobioassay.



PART 3 Respiratory Protection Program

Respiratory protection equipment includes NIOSH- approved respirators with particulate or gas-filtering cartridges, supplied air respirators, self-contained breathing apparatus and airline supplied-air suits and hoods.

531 Requirements

1. Use of respiratory protection shall be reduced to the minimum practicable by implementing engineered controls and work practices to contain radioactivity at the source.
2. Respirators shall be issued only to personnel who are trained, fitted and medically qualified to wear the specific type of respirator. Training and qualification testing shall be performed as specified in the *EH&S Manual* Chapter **6630 Respiratory Protection**.
3. The use of respiratory protection for radiological controls shall be done in accordance with the Jefferson Lab respiratory protection program as specified in the *EH&S Manual* Chapter **6630 Respiratory Protection**.



PART 4 Handling Radiologically Contaminated Personnel

541 Skin Contamination

1. When personnel detect skin contamination, they shall notify the Radiological Control Group.
2. The extent of skin contamination should be determined prior to initiating decontamination procedures.
3. Skin decontamination methods should be non-invasive. Skin abrasion should be avoided during the decontamination process. Any decontamination with the possibility of causing injury shall be performed under the auspices of Jefferson Lab Occupational Health & Safety personnel. See National Council on Radiation Protection and Measurements Report Number 65. Medical treatment of injuries takes precedent over radiological considerations.
4. Personnel with skin contamination that may cause a dose greater than the alert level in Tables [2-1A](#) and [2-1B](#) shall be assessed and should be informed of their initial dose estimate as soon as practicable. An assessment of skin exposure requires time to conduct a detailed evaluation. Final dose assessments should be explained to the persons affected as soon as practicable.
5. The treatment of contaminated injuries should be coordinated with Jefferson Lab Occupational Health & Safety or other appropriate medical personnel.

PART 5 Radiological Monitoring and Surveys

Monitoring of radiation is performed using fixed (area) or portable radiation instruments, or a combination thereof. Both the fixed and portable instruments must be readily available and capable of measuring ambient radiation dose rates for the purpose of controlling radiation exposures. Prior to starting any operation that could produce radiation, all stationary instruments should be checked to ensure their proper operation. A review of the central computer data logging system for area monitor malfunction is adequate to verify proper operation. Periodic surveys outside of the operating area are typically performed according to a schedule. Portable instruments should be source checked prior to and after a survey if possible. All portable instruments shall undergo a periodic source check performed by a qualified RCT or ARM. This source check shall be documented on the portable instrument.

551 Requirements

1. Monitoring of individuals and areas shall be routinely performed, as necessary, to identify and control potential sources of personnel exposure to radiation and/or radioactive material. Monitoring of individuals and areas shall be performed to:
 - a. Demonstrate compliance with 10 CFR 835
 - b. Document radiological conditions;
 - c. Detect changes in radiological conditions;
 - d. Detect the gradual buildup of radioactive material;
 - e. Verify the effectiveness of engineered and process controls in containing radioactive material and reducing radiation exposure; and
 - f. Identify and control potential sources of individual exposure to radiation and/or radioactive material.
2. Instruments and equipment used for monitoring shall be:
 - a. Periodically maintained and calibrated on an established frequency;
 - b. Appropriate for the type(s), levels, and energies of the radiation(s) encountered;
 - c. Appropriate for existing environmental conditions; and
 - d. Routinely tested for operability.
3. Only trained and qualified personnel shall perform monitoring.
4. The cognizant radiological supervisor shall review monitoring results. The review should ensure that all required surveys have been performed and that the documentation is accurate and complete.
5. Results of current surveys or survey maps should be conspicuously posted to inform personnel of the radiological conditions.
6. Monitoring results should be made available to line management and used in support of pre- and post-job evaluations, ALARA preplanning, contamination control and management of radiological control operations.

552 Controlled Area Radiation Monitors (CARMs)

Fixed instruments are used to provide an indication of area radiation levels, provide a record of area dosimetry for ALARA program purposes and for protective trip functions where they prevent situations that could cause persons to exceed certain dose limits. Only RCG staff may direct the movement or placement of CARM probes. The calibration, use, and functional certification of these instruments in safety related systems are the responsibility of the RCG.

1. The need and placement of area radiation monitors shall be documented and assessed when changes to facilities, systems or equipment occur.
2. Area radiation monitors shall be tested at least semi-annually to verify audible alarm system operability and audibility under ambient working conditions and operability of visual alarms when so equipped. Interlock function shall be tested at least annually.
3. If installed instrumentation is removed from service for maintenance or calibration, a radiation monitoring program providing at least equal detection capability should be maintained, consistent with the potential for unexpected increases in radiation dose rates.

553 Contamination Control Surveys

Appropriate controls shall be maintained and verified which prevent the inadvertent transfer of removable contamination to locations outside of radiological areas under normal operating conditions. Any area in which contamination levels exceed the values specified in [Table 2-2](#) shall be controlled in a manner commensurate with the physical and chemical characteristics of the contaminant, the radionuclides present, and the fixed and removable contamination levels.

1. In addition to the requirements of [Article 551](#), routine contamination surveys should be conducted as follows:
 - a. Prior to transfer of equipment and material from contaminated areas or highly contaminated areas
 - b. Daily, at contamination area control points, change areas, or step-off pads when in use, or per shift in high use situations
 - c. Weekly, or upon entry if entries are less frequent, where contamination boundaries or postings are located
 - d. During initial entry into a known or suspected contamination area, periodically during work, at completion of job, or as specified in a Radiological Work Permit
 - e. After a leak or spill of radioactive materials.
2. Items with inaccessible surfaces which were located in known or suspected contamination areas and have the potential to become contaminated at levels likely to exceed [Table 2-2](#) values should be treated as potentially contaminated and subject to administrative controls unless the items are dismantled and monitored or special survey techniques are used to survey all surfaces.

3. Appropriate methods shall be used for assessing representative samples of bulk material, such as sand, sweeping compounds or plate steel which are not suitable for normal loose and fixed contamination-level assessment techniques.
4. Swipe surveys for removable contamination shall be reported in units of disintegrations per minute per 100 cm² (dpm/100 cm²). For swipe surveys of small items covering less than 100 cm², the results shall be reported in units of dpm per area swiped.
5. Large area wipes should be used to supplement standard swipe techniques in areas generally assumed not to be contaminated. If an evaluation indicates that an area wiped is contaminated, a thorough contamination swipe survey should be performed.
6. Areas identified as either contaminated with, or having the potential for being contaminated with, highly radioactive particles (“hot particles”) should be surveyed weekly. These areas should be surveyed at least daily during periods of work that may result in the generation of hot particles. Special swipe techniques to collect hot particles, such as tape and large area wipes, should be used.
7. Surveys should also take into account the potential for fixed contamination. Areas with fixed contamination exceeding the total radioactivity values specified in [Table 2-2](#) may be located outside of radiological areas provided all the following conditions are met:
 - a. Removable contamination levels are below the levels specified in [Table 2-2](#);
 - b. Unrestricted access to the area is not likely to cause any individual to receive a total effective dose equivalent in excess of 0.1 rem in a year;
 - c. The area is routinely monitored;
 - d. The area is clearly marked to alert personnel of the contaminated status;
 - e. Appropriate administrative procedures are established and exercised to maintain control of these areas.

554 Airborne Radioactivity Monitoring

In addition to the requirements of [Article 551](#), air monitoring equipment should be used in situations where airborne radioactivity levels can fluctuate and early detection of airborne radioactivity could prevent or minimize inhalation of radioactivity by personnel. Selection of air monitoring equipment should be based on the specific job being monitored. Air monitoring equipment includes portable and fixed air sampling equipment and continuous air monitors. Samples are taken as necessary to detect and evaluate the level or concentration of airborne radioactive material at work locations.

1. Monitoring of airborne radioactivity shall be performed:
 - a. Where an individual is likely to receive an exposure of 40 or more DAC-hours in a year; or
 - b. As necessary to characterize the airborne radioactivity hazard where respiratory protective devices for protection against airborne radionuclides have been prescribed.
2. Real-time air monitoring shall be performed as necessary to detect and provide warning of airborne radioactivity concentrations that warrant immediate action to terminate inhalation of airborne radioactive material.



3. Air sampling equipment should be positioned to measure air concentrations to which persons are exposed. If this cannot be achieved, a program of personal breathing-zone air sampling will be initiated.
4. Air monitoring equipment shall be routinely calibrated and maintained at a frequency of at least once per year. Continuous air monitors should be capable of measuring 1 DAC when averaged over 8 hours (8 DAC-hours) under laboratory conditions.
5. For the airborne radioactive material that could be encountered, real-time air monitors shall have alarm capability and sufficient sensitivity to alert exposed or potentially exposed individuals that immediate action is necessary in order to terminate or minimize inhalation exposures.
6. The proper operation of continuous air monitoring equipment should be periodically verified by observing relevant computer records of continuously logged operational parameters. Operational checks should include positive air-flow indication, non-zero response to background activity, and internal check sources.

555 Receipt of Packages Containing Radioactive Material

1. If packages containing quantities of radioactive material in excess of a Type A quantity (as defined at 10 CFR 71.4) are expected to be received from radioactive material transportation, arrangements shall be made to either:
 - a. Take possession of the package when the carrier offers it for delivery; or
 - b. Receive notification as soon as practicable after arrival of the package at the carrier's terminal and to take possession of the package expeditiously after receiving such notification.
2. Upon receipt from radioactive material transportation, external surfaces of packages known to contain radioactive material shall be monitored if the package:
 - a. Is labeled with a Radioactive White I, Yellow II, or Yellow III label (as specified at 49 CFR 172.403 and 172.436-440); or
 - b. Has been transported as low specific activity material (as defined at 10 CFR 71.4) on an exclusive use vehicle (as defined at 10 CFR 71.4); or
 - c. Has evidence of degradation, such as packages that are crushed, wet, or damaged.
3. The monitoring required by paragraph (2) of this section shall include:
 - a. Measurements of removable contamination levels, unless the package contains only special form (as defined at 10 CFR 71.4) or gaseous radioactive material; and
 - b. Measurements of the radiation levels, unless the package contains less than a Type A quantity (as defined at 10 CFR 71.4) of radioactive material.
4. The monitoring required by paragraph (2) of this section shall be completed as soon as practicable following receipt of the package, but not later than 8 hours after the beginning of the working day following receipt of the package.



PART 6 Instrumentation and Calibration

561 Availability at Jefferson Lab

The RCG is responsible for the maintenance, calibration, and operability of radiation detection equipment. Instruments used for monitoring and contamination control shall be:

- a. Maintained and periodically calibrated on an established frequency of at least once per year;
- b. Appropriate for the type(s), levels, and energies of the radiation(s) expected;
- c. Appropriate for existing environmental conditions; and
- d. Routinely tested for operability.

562 Use of Radiation Monitoring Instruments

1. Prior to using an instrument, checks should be made by the RCT or ARM:
 - a. Visual check -- Check for physical integrity of the instrument. Discrepancies include loose or broken knobs and switches, broken probe cords, broken probes, and cracked meters.
 - b. Check instrument calibration due date. Do not use an instrument that is overdue for calibration.
 - c. Battery check -- All battery powered instruments with a "battery check" switch position shall be checked prior to use. A meter reading in the indicated range is the indication of a successful battery check.
 - d. Function check -- Where provided, follow posted instructions and perform a source check on the instrument. Sources are installed in a test rig and a list of acceptable responses is provided.
2. If any discrepancies are noted during the performance of the above checks, a "Faulty Instrument" tag should be filled out and attached to the instrument. The instrument should be returned to the RCG and a replacement obtained. **UNDER NO CIRCUMSTANCE SHOULD A FAULTY INSTRUMENT BE USED.**
3. When choosing an instrument, care should be taken to select one with a range high enough for the expected conditions. Not only will having the incorrect instrument waste time, but it will also unnecessarily increase radiation exposure.
4. The correct instrument for use on any given survey shall be determined by the RCG.
5. When entering an area where the level of the radiation field is unknown, the instrument shall be set to operate on the highest range until it is seen that the meter reads less than one quarter of the full scale. The operating switch should then be moved to successively lower ranges until the indicated reading is between one quarter and three quarters of the full scale or the lowest range is reached. Note that auto-ranging instruments will select the correct range for the user.
6. After use, the instrument should be returned to its appropriate storage location. Ensure that the instrument is turned off prior to storage. Instruments that appear damaged, that failed response checks, or that may otherwise be unfit for future use shall be tagged and returned to the RCG and a replacement obtained.



563 Inspection, Calibration and Performance Tests

1. Radiological instruments shall be used only to measure the radiation for which their calibrations are valid. Instrumentation shall be calibrated annually and source checked quarterly. Records of calibration and repair will be kept for each instrument. National Institute of Standards Technology (NIST) traceable sources shall be used for calibrations.
2. Calibration procedures shall be maintained for each instrument type and include frequency of calibration, recalibration requirements, primary calibration requirements, periodic performance test requirements, calibration record requirements and maintenance requirements.
3. Radiation instrumentation response to interfering ionizing and non-ionizing radiation and environmental conditions should be known prior to use.
4. Functional tests shall be used to assess instrumentation designs that include alarms or that involve a process control. A functional test shall be performed to test all components involved in an alarm or trip function and should be performed at least annually.
5. In unusual and limited situations it may be necessary to use an instrument in an application other than that envisioned by the manufacturer. The instrument shall be adjusted, calibrated and/or labeled as appropriate to identify the special conditions and used only under the special conditions for which it was calibrated.
6. Instruments shall bear a label or tag with the date of calibration and date calibration is due.
7. Instruments whose "as found" readings indicate that the instrument may have been used while out of calibration shall be reported to the Radiation Control Group. The Radiation Control Group shall review surveys performed with the instrument while it was out of calibration.

564 Maintenance

1. A program for preventive and corrective maintenance of all radiological instrumentation shall be maintained and documented.
2. Preventive and corrective maintenance should be performed using components and procedures at least as stringent as those specified by the manufacturer of the instrument.
3. Radiological instruments shall undergo calibration prior to use following any preventive or corrective maintenance or any adjustment that voids the previous calibration. A battery change is not normally considered maintenance.

565 Calibration Facilities

1. Calibration facilities should perform inspections, calibrations, performance tests, calibration equipment selection and quality assurance in accordance with the recommendations of ANSI N323 and take the following actions:
 - a. Locate activities in a manner to minimize radiation exposure to operating personnel and to personnel in adjacent areas
 - b. Minimize sources of interference, such as backscatter and non-ionizing radiation, during the calibration of instrumentation and correct for interferences as necessary



- c. Operate in accordance with the referenced standards
 - d. Generate records of calibration, functional tests and maintenance in accordance with the referenced standards.
2. For calibrations unable to be performed by Jefferson Lab, contracted calibration services should be performed in accordance with Jefferson Lab approved procedures.

566 Radiation Safety Interlocks

Safe operations require that a number of electrical and mechanical conditions be satisfied before radiation production can begin. As described in EH&S Manual Chapter **6311 *Prompt Radiation Control***, interlock systems are designed to ensure that these conditions are satisfied. Interlocks are designed to be “fail safe” and to have considerable redundancy in the system.

Interlock systems shall be described in the work control document approved for the operation. Periodic testing of the interlock systems shall be used to verify system integrity.



Chapter 6: Training and Qualification

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REFERENCES

- 10 CFR 835
- Jefferson Lab Radiation Worker Program Management Manual
- Jefferson Lab RCT Program Management Manual
- 10 CFR 34.43

PART 1 General Requirements

611 Purpose

All individuals shall be trained in radiation safety prior to being permitted unescorted access to controlled areas and prior to receiving occupational dose. This chapter establishes the requirements to ensure that training is commensurate with the hazards and control and to maintain the radiation exposures As-Low-As-Reasonably-Achievable (ALARA). Training requirements in this chapter apply to personnel entering a Jefferson Lab (JLab) Controlled Area, including employees of the Department of Energy, subcontractors, service companies, other federal agencies, state and local governments, and visitors.

612 Standardization

1. Applicable portions of the DOE standardized core courses and training materials should be used as the basis for radiological training at JLab. In addition, site specific training materials will be used to instruct and qualify personnel for radiological work at the JLab site.
2. Radiological worker training not specific to a given site or facility may be waived provided that:
 - a. This training has been received at another DOE site or facility within the past 2 years;
 - b. There is provision of proof-of-training in the form of a certification document containing the individual's name, date of training, and specific topics covered; and
 - c. An appropriate official has certified the training of the individual.
 - d. Training reciprocity is also contingent on completion of any Jefferson Lab site-specific training modules and performance demonstration requirements, and completion of a closed book written or oral exam.
3. Pocket cards or other documentation that identifies current Jefferson Lab training status will be provided on request to assist in training reciprocity when traveling to other DOE facilities.
4. The site Radiation Control Manager or a designee shall review and approve site-generated radiological training material.
5. Radiation safety training shall include, as a minimum, the following topics:
 - a. Risks of exposure to radiation and radioactive materials, including prenatal radiation exposure;
 - b. Basic radiological fundamentals and radiation protection concepts;
 - c. Physical design features, administrative controls, limits, policies, procedures, alarms, and other measures implemented at the facility to manage doses and maintain doses ALARA, including both routine and emergency actions;
 - d. Individual rights and responsibilities as related to implementation of the facility radiation protection program;
 - e. Individual responsibilities for implementing ALARA measures required by Article 111; and
 - f. Individual exposure reports that may be requested in accordance with Articles 732, 781.



613 Requirements

It is the responsibility of the employee and their supervisor to ensure that they have scheduled appropriate radiation safety training prior to performing work that requires such training.

1. The knowledge of radiation safety possessed by radiation workers shall be verified by successful completion of a written examination and performance demonstration of skills. Examinations should be used for General Employee Radiation Training (GERT), and shall be used for Radiological Worker I (RW I), Radiological Worker II (RW II), and Radiological Control Technologist (RCT) qualification to demonstrate satisfactory completion of theoretical and classroom material. Examinations should be written or computer based training examinations, however alternatives may be used to accommodate special needs. The written examination process requires:
 - a. A minimum passing score for each training program be established
 - b. That true/false questions not be included
 - c. Use of questions randomly selected from the question bank
 - d. If challenging a training course by exam, acknowledgment by signature that the student has completed course of self study prior to taking the exam
 - e. Acknowledgment by signature that the student participated in a post-examination review
 - f. Remedial actions for failure to meet the minimum score
 - g. That questions be selected to test what the student is expected to remember months after the training rather than to test short-term memory of theoretical material.
2. The initial performance demonstration process requires:
 - a. Identification of specific performance elements that are related to the training objectives.
 - b. A minimum passing score for the performance demonstration to be established, and where appropriate, identification of specific performance elements that must be satisfactorily demonstrated.
 - c. An opportunity for the trainee to ask questions, practice, or otherwise prepare for the performance demonstration.
 - d. That given adequate preparation opportunity, the trainee should not be coached by the instructor during the performance demonstration.
 - e. A simulation or mock-up of a radiological area or areas adequate to allow demonstration of the required performance elements in a safe and controlled environment.
 - f. Remedial actions for failure to meet the minimum score.
3. Training should address both normal and abnormal radiological situations. Retraining shall be provided when there is a significant change to radiation protection policies and procedures that affect general employees and shall be conducted at intervals not to exceed 24 months.
4. General Employee Radiological Training and Radiological Worker Training shall be valid for 24 months. Changes to the program shall be incorporated as they are identified and a decision made if retraining is needed prior to the 24-month period.
5. Training shall include changes in requirements and should include updates of relevant lessons learned from operations and maintenance experience and occurrence reporting, for the site and for other DOE facilities when applicable.
6. Verification of the effectiveness of radiological control training should be accomplished by observing or testing a subset of trained workers in the workplace.



7. Reading and comprehension skills in the English language are generally necessary for General Employee Radiological Training and Radiation Worker I training. If the instructor is unable to verify that the student can comply with written and/or verbal instructions in the English language, the instructor shall not qualify the student. In some cases, visitor orientation and the use of trained escorts may provide a temporary alternative to Radiological Worker Training with the concurrence of the Radiation Control Manager and the Jefferson Lab sponsor. When an escort is used in lieu of training, the escort shall (1) have completed radiation safety training, examinations, and performance demonstrations required for entry to the area and performance of the work; and (2) ensure that all escorted individuals comply with the documented radiation protection program.
8. Training records and course documentation shall meet the requirements of [Article 725](#).

614 Qualification Standards for the Radiological Control Technologist (RCT)

1. Qualification Standards define the requirements for demonstrating completion of training. Qualification Standards applicable to Jefferson Lab are found in the Jefferson Lab RCT Program Management Manual.
2. Qualification Standards used in the Jefferson Lab RCT Program Management Manual should be based on applicable standards including DOE-suggested training materials, and are supplemented to include Jefferson Lab site-specific elements.
3. Qualification Standards for the Radiological Control Technologist position include on-the-job training to provide hands-on experience directly applicable to the job and are specified in individual training plans for each technologist.
4. On-the-job trainees shall be under the control of qualified personnel. Before performing a job function without direct supervision, a trainee with partially completed qualifications shall have completed the qualifications for that task.

615 Instructor Training and Qualifications

1. Instructors shall have the technical knowledge, experience and instructional skills required to fulfill their assigned duties. The decision for the suitability of a staff member to serve as an instructor rests with the RadCon Manager.
2. Instructors-in-training shall be monitored by a qualified instructor.
3. Subject matter experts without instructor qualification may provide training in their areas of expertise.

PART 2 General Employee Radiological Training

621 Site Personnel

Personnel who have unescorted access to a controlled area (CA) can encounter Radiologically Controlled Areas (RCAs) with radiological barriers, postings or radioactive materials. Consequently these employees shall maintain, as a minimum, General Employee Radiological Training.

1. General Employee Radiological Training should include DOE-recommended training materials and additional site-specific information as appropriate.
2. Additional training beyond General Employee Radiological Training is necessary for unescorted entry into Radiologically Controlled Areas.
3. Information may be communicated by classroom lecture, videotape, or other applicable methods.

622 Radiological Orientation for Visitors, Tour Groups, and Other Untrained Individuals

1. Visitors who enter a Controlled Area must be escorted by an individual who is qualified with General Employee Radiological Training or higher training.
2. Visitors who enter a Radiologically Controlled Area shall be escorted and receive a radiological safety orientation that includes the following topics:
 - a. Basic radiation protection concepts
 - b. Risk of low-level occupational radiation exposure, including cancer and genetic effects
 - c. Risk of prenatal radiation exposure
 - d. Radiological protection policies and procedures
 - e. Visitor responsibilities for radiation safety
 - f. Adherence to radiological posting and labeling
 - g. Applicable emergency procedures
 - h. Information may be communicated by videotape, orally, and/or handout to personnel entering a site.
3. Records of the orientation shall be maintained. The Jefferson Lab Visitor Information Sheet, including visitors' signatures, shall suffice as documentation of visitor orientation.

PART 3 Radiological Worker Training

631 Requirements

The knowledge of radiation safety possessed by radiological workers shall be verified by examination and performance demonstration prior to an unsupervised assignment. The level of training shall be commensurate with each worker's assignment.

1. Radiological Worker I (RW I) training shall be completed prior to entering Radiologically Controlled areas without a qualified escort.
2. Radiological Worker I training shall be completed prior to performing unescorted assignments as a radiological worker.
3. Radiological Worker II (RW II) training is required for entry into areas as stated in [Table 6-1](#).
4. Additional training may be required for special job functions with radiological consequences.

632 Radiological Worker I

1. Training for radiological workers shall either precede assignment as a radiological worker or be concurrent with assignment as a radiological worker if the worker is accompanied by and under the direct supervision of a trained radiological worker.
2. Radiological Worker I training shall consist of applicable portions of the DOE standardized core course training materials, shall emphasize site-specific information, and course work shall include both classroom and applied training.
3. Jefferson Lab Radiological Worker I training shall include procedures specific to an individual's job assignment and so encompass, at a minimum, the following performance demonstration elements:
 - a. Entering and exiting simulated Controlled Areas, Radiation Areas, and High Radiation Areas,
 - b. Reading and interpreting applicable personnel dosimetry devices and instrumentation and taking appropriate actions based on the readings,
 - c. Use of RWPs,
 - d. Anticipated response to abnormal situations.
4. Personnel who maintain qualifications as Radiological Worker I satisfy the requirements of GERT Training.



633 Radiological Worker II

Workers whose job assignments involve performing work in containments, entry into Contaminated Areas, or Airborne Radioactivity Areas shall complete Radiological Worker II training.

1. Radiological Worker II training shall consist of applicable portions of the standardized core course training materials and shall emphasize site-specific information.
2. Jefferson Lab Radiological Worker II training shall include procedures specific to an individual's job assignment and so encompass, at a minimum, the following site-specific practical factors:
 - a. The use of protective clothing
 - b. Performance of tasks in simulated Contaminated Areas
 - c. Anticipated response to simulated abnormal situations
 - d. Performance of monitoring for personnel contamination
 - e. Verification of instrument response and source check.
3. Respiratory protection training is not covered in Radiological Worker II training (see Article 531).

634 Specialized Radiological Worker Training

When necessary Specialized Radiological Worker training will be given by the RCG for non-routine operations or work in areas with changing radiological conditions. This training is in addition to Radiological Worker training and addresses planning, preparing, and performing jobs that have the potential radiation doses in excess of the applicable values in Article 211, Table 2-1A and 2-1B. Such jobs may involve special containment devices, respiratory training, the use of mockups, and ALARA considerations.

Table 6-1 Radiological Worker Entry Training Requirements

Areas	Radiological Worker I	Radiological Worker II**
Entry into Radiation Areas (<100 mrem/hr)	YES	NO
Entry into High or Very High Radiation Areas (≥ 100 mrem/hr)	YES*	NO
Entry into Contamination Areas and High Contamination Areas	NO	YES
Entry into Airborne Radioactivity Areas	NO	YES***

* Entry requirements further restricted by Article 334. Further training may be necessary as specified in Article 634.

** Full RadWorker II includes Rad Worker I qualification.

*** Rad Worker II qualification not required when airborne isotopes of concern have a DAC based on immersion dose as listed in Appendix 2E.

PART 4 Radiological Control Staff Training

641 Radiation Control Technologists

Training and retraining programs for Radiological Control Technologists (RCTs) shall be established and conducted at intervals not to exceed two years to familiarize technologists with the fundamentals of radiation protection and the proper techniques for maintaining doses ALARA.

1. Training and qualification of Radiological Control Technologists and their immediate supervisors shall address routine operations and also focus on recognizing and handling situations in both normal and changing radiological conditions.
2. Newly qualified technologists and those still in training should be given the opportunity to work with qualified, experienced technologists to foster development.
3. Course content, material development requirements, standards and policies, and administration of Radiological Control Technologist Training are fully defined and described in the Jefferson Lab Radiological Control Technologist Program Management Manual.
4. Radiological Control Technologist qualification consists of a program of classroom training, on-the-job training according to the Qualification Standards, and passing written examinations and performance demonstration evaluations.
5. Radiological Control Technologist training shall use the applicable portions of the standardized core course training materials and in addition shall emphasize Jefferson Lab site-specific information.
6. Radiological Control Technologist candidates who have prerequisite knowledge, such as college credit, operational experience or related qualifications, may satisfy individual sections of the standardized core course training requirements by passing comprehensive challenge examinations. In addition, allowance may be made for previous training on generic radiation safety topics (i.e., those not specific to a site or facility), provided that documentation of the previous training is obtained.
7. Entry-level prerequisites shall be established to ensure that Radiological Control Technologists meet standards for physical condition and education. These standards should include the following:
 - a. High school education or equivalency
 - b. Fundamentals of mathematics, physics, chemistry and science
 - c. Systems and fundamentals of process, operations and maintenance
 - d. Reading and comprehension level sufficient to follow procedures, write permits, prepare survey maps, write reports and prepare shipping and transfer permits
 - e. Ability to work in a support role, including communicating verbal instructions to others
 - f. Physical requirements to handle Personal Protective Equipment, other equipment and assist others in work locations, commensurate with assignment.



8. Radiological Control Technologists are encouraged to pursue registration by the National Registry of Radiation Protection Technologists (NRRPT).
9. Registration by the NRRPT shall be considered equivalent to completion of the core training requirements.
10. The Radiological Control Technologists training program shall include procedures specific to the site or facility where the technologist is assigned and shall be commensurate with the technologist's assignment.
11. The training for radiological control technologists shall either precede performance of tasks assigned to radiological control technologists or be concurrent with such task assignments if the individual is accompanied by and under the direct supervision of a trained individual.
12. The required level of knowledge of radiation safety possessed by radiological control technologists shall be verified by examination to include demonstration prior to any unsupervised work assignment.

642 Continuing Training

1. Following initial qualification, the Radiological Control Technologist should begin a cycle of continuing training required for requalification. This cycle is established and conducted at intervals not to exceed 24 months in order to ensure familiarity with the fundamentals of radiation protection and the proper procedures for maintaining exposures ALARA. Requirements for requalification are based on a job analysis and may include a comprehensive written examination and performance demonstrations.
2. Continuing training should provide continued improvement in the knowledge and skills of the Radiological Control Technologist.
3. Continuing training should include site-specific and DOE-wide changes in requirements and updates of lessons learned from operating experience and industry events.
4. Personnel who maintain qualifications as Radiological Control Technologists satisfy the requirements of Radiological Worker I and Radiological Worker II Training.

643 Radiological Control Technologist Supervisors

1. Radiological Control Technologist Supervisors shall maintain training in tasks they supervise or perform.
2. Radiological Control Technologist Supervisors should have supervisory and leadership capabilities to direct the work of technologists; effectively interact with line supervisors, professional staff, and other managers; and be able to respond and direct others in emergency and abnormal situations.

644 Radiological Control Personnel

1. Radiological Control technical staff and management shall have:
 - a. A combination of education and experience commensurate with their job responsibilities
 - b. Continuing training based on an assessment of job responsibilities to maintain and enhance proficiency
 - c. Continuing training to remain cognizant of changes to the facility, operating experience, procedures, regulations and quality assurance requirements.

2. Radiological support personnel shall have:
 - a. Training on Radiological Worker I, II, or Radiological Control Technologist training and additional job-specific topics, as applicable
 - b. Training appropriate to the tasks to be performed
 - c. Continuing training to provide continued improvement in knowledge and skills.
 - d. Certification and involvement with professional industry organizations is encouraged.

645 Assigned Radiation Monitors (ARMs)

Assigned Radiation Monitors (ARMs) are individuals not under the permanent employ of the Radiation Control Group, but who have specific training provided from the RCG on the proper conduct and documentation of radiation surveys. ARMs are authorized to perform and document initial radiation surveys when an accelerator enclosure or experimental hall has the Safety System status changed from “beam permit” or “power permit” to “controlled access”. When performing these duties, the ARMs are working under the auspices of the RCG.

646 Radiographers and Radiation-Generating Device Operators

Radiographers shall have training in accordance with 10 CFR 34.43. Radiation Generating Device Operators should have training comparable to that required by 10 CFR 34.43. They shall also follow the provisions of this manual and any specific instructions given to them by the Radiation Control Staff.

647 Emergency Response Personnel

Nothing in this manual shall be construed as limiting actions that may be necessary to protect health and safety. Provisions shall be in place to accommodate rapid site and radiological area access by on-site and off-site emergency workers such as firefighters, medical personnel, and security personnel. These provisions should include training, escorts, and dosimetry as appropriate to the situation. Training should emphasize that lifesaving has priority over radiological controls.



Chapter 7: Radiological Records

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REFERENCES:

The following reference documents are used for guidance regarding this chapter. The CFR web site <http://www.gpoaccess.gov/cfr/index.html> contains further information on this reference material.

ANSI N13.6 -- 1999

5 USC 552a (Privacy Act)

INPO 85-004

10 CFR 20

NUREG 0761

10 CFR 835

PART 1 Requirements

711 Purpose

This chapter contains the prescribed practices for preparing and retaining radiologically related records. Records are maintained to document compliance with applicable parts of 10 CFR 835 and specifically with radiation protection programs. Radiological control records are also needed to demonstrate the effectiveness of the overall program. The work force and management are required to use records to document radiological safety afforded to personnel on-site. Records of the Jefferson Lab (JLab) radiological program may be required to support worker health studies and future disputes or claims. Therefore, these records should be high quality, readily retrievable and managed for the prescribed retention period. Data necessary for future verification or reassessment of the recorded doses shall be recorded. Unless otherwise specified in this text, records are retained until DOE authorizes final disposition. Records shall be handled such that personal privacy is protected.

712 Records Management Program

1. There are specific records maintenance requirements for occupational exposure in excess of thresholds identified in Articles 212 through 217 and doses received during planned special exposures, accidents, and emergency conditions. A radiological records management program ensures that auditable records and reports are controlled through the stages of creation, distribution, use, arrangement, storage, retrieval, media conversion (if applicable) and disposition. The records management program shall include the following:
 - a. Radiological Policy Statements
 - b. Radiological Control Procedures
 - c. Individual Radiological Doses
 - d. Internal and External Dosimetry Policies and Procedures (including Bases Documents)
 - e. Personnel Training (course records and individual records)
 - f. ALARA Records
 - g. Radiological Instrumentation Test, Repair and Calibration Records
 - h. Radiological Surveys
 - i. Area Monitoring Dosimetry Results
 - j. Radiological Work Permits
 - k. Radiological Performance Indicators and Assessments
 - l. Radiological Safety Analysis and Evaluation Reports
 - m. Quality Assurance Records
 - n. Radiological Incident and Occurrence Reports (and Critique Reports, if applicable)
 - o. Accountability records for sealed sources
 - p. Records for release of material to Controlled and Uncontrolled Areas
 - q. Reports of loss of radioactive material
 - r. Internal and External Audits
 - s. Descriptions and/or records of changes in equipment, techniques, and procedures used for monitoring in the workplace.



2. Recording of the non-uniform shallow dose equivalent to the skin caused by contamination on the skin is not required if the dose is less than 2 percent of the limit specified for the skin in [Table 2-1B](#).
3. Where radiological services (for example, dosimetry and laboratory analyses) are purchased, there should be a clear agreement regarding records responsibility and auditability during performance of the service. Records of results should reside with the RCG.
4. Records and reports containing private information should be locked when unattended. Private information, for the purposes of this Chapter, is records or reports that contain information such as full social security number, age, sex, national origin, etc. Magnetic media containing Privacy Act Information shall be stored in a locked container and shall have password protection applied for access to this information.
5. Privacy Act information shall be controlled to prevent unauthorized release.
6. Superseded or revised documents shall be archived for future retrieval.
7. All records required by this Chapter shall be transferred to the DOE upon cessation of activities at the site that could cause exposure to individuals.
8. The records specified in this Chapter that are identified with a specific individual shall be readily available to that individual.

713 Recordkeeping Standards

1. Radiological control records shall be accurate and legible. The records should include the following:
 - a. Identification of the facility, specific location, function and process
 - b. Signature or other identifying code of the preparer, date, and time (if applicable)
 - c. Legible entries in blue or black ink
 - d. Corrections identified by a single line-out, initialed and dated
 - e. Supervisory signature to ensure review and proper completion of forms.
2. The Radiation Control Group should maintain a file of names, signatures and initials for future identification of the person who signed or initialed a record.
3. Radiological control records should not include:
 - a. Opaque substances for corrections
 - b. Shorthand or other nonstandardized terms.

All individual monitoring records must be sufficient to evaluate compliance with Articles 212-217, Tables 2-1A and 2-1B, which state occupational exposure limits and must be sufficient to provide dose information necessary to complete reports required by Article 781.



PART 2 Employee Records

721 Employment History

Efforts shall be made to obtain records of prior years occupational internal and external exposure. Records obtained which detail an employee's pre-employment and employment history and the associated radiation dose shall be maintained. Where practical, the association between the radiation dose and job function should be preserved for trending purposes and future worker health studies. The following information shall be maintained:

1. Previous work history detailing radiological work assignments and yearly doses at other facilities, to the extent practical.
2. In the absence of formal records of previous occupational exposure during the year, a written estimate signed by the individual may be accepted.
3. Nuclear Regulatory Commission Form 4 or equivalent that documents previous occupational radiation doses.

722 Personnel Radiological Records

1. Records shall be maintained to document doses received by all individuals for whom monitoring was required pursuant to [Chapter 2, Part 1](#) and to document doses received during planned special exposures, unplanned doses exceeding the monitoring thresholds of [Chapter 2, Part 1](#), and authorized emergency exposures.
2. The results of individual external and internal dose monitoring that is performed, but not required by [Chapter 2, Part 1](#), shall be recorded. Recording of the non-uniform shallow dose equivalent to the skin is not required if the dose is less than 2 percent of the limit specified for the skin at [Table 2-1B](#).
3. Radiation dose records shall contain information sufficient to identify each person, including social security or employee number.
4. Routine and special records related to radiation doses shall be retained for each person monitored. This shall include records of zero dose. Procedures, data and supporting information needed to reconfirm a person's dose at a later date should be maintained. Documentation of all occupational exposure received during the current year shall be obtained when demonstrating compliance with limits in Articles [212-217](#), Tables [2-1A](#), [2-1B](#).
5. The individual monitoring records shall include the following quantities for external dose received during the year:
 - a. The effective dose equivalent from external sources of radiation (deep dose equivalent may be used as effective dose equivalent for external exposure);
 - b. The lens of the eye dose equivalent;
 - c. The shallow dose equivalent to the skin;
 - d. The shallow dose equivalent to the extremities;
 - e. Evaluations resulting from anomalous dose results such as unexpected high or low doses;
 - f. Dose reconstructions from lost or damaged dosimeters, or for non-badged workers;
 - g. Include the dose equivalent to the embryo/fetus of a declared pregnant worker.



6. The individual monitoring records shall include the following quantities for internal dose resulting from intakes received during the year:
 - a. Committed effective dose equivalent;
 - b. Committed dose equivalent to any organ of tissue of concern;
 - c. Estimated intake and identity of radionuclides.
7. The individual monitoring records shall include the following quantities for the summation of the external and internal dose:
 - a. The total effective dose equivalent in a year;
 - b. The sum of the deep dose equivalent from external exposures and the committed dose equivalent to that organ or tissue for any organ or tissue assigned an internal dose during the year;
 - c. The cumulative total effective dose equivalent received from external and internal sources while employed at the site or facility, since January 1, 1989.
8. Counseling of individual persons about radiological concerns should be documented and this documentation retained.
9. Records of authorization to exceed Administrative Control Levels shall be retained.

723 Other Personnel Radiological Records

1. The complete records of radiological incidents and occurrences involving personnel dose shall be retained.
2. Records of employee radiological safety concerns that have been formally investigated and documented shall be maintained.
3. Written declarations of pregnancy, including the estimated date of conception, and revocations of declarations of pregnancy shall be maintained. Records indicating that the pregnancy has concluded should also be maintained.

724 Medical Records

1. Medical evaluations performed in support of the radiological program shall be documented.
2. Records of non-occupational radiation doses, such as therapeutic or large amounts of diagnostic radiation doses for medical purposes should be maintained when made available by the employee.

725 Radiological Training and Qualification Records

1. Records of training and qualification in radiological control shall be maintained to demonstrate that a person received appropriate information to perform the work assignment in a safe manner and to document compliance with Chapter 6, Parts 1 through 4. Qualification standard records shall be retained for on-the-job and practical factor training as well as for formal classroom training.



2. Formal records of training and qualification should be readily available to first-line supervision and management of involved personnel to aid in making work assignments.
3. Personnel training records shall be controlled and retained to meet the requirements of 10 CFR 835.704. At a minimum, these records shall include the following:
 - a. Course title
 - b. Attendance sheets (or electronic record) with instructor's name
 - c. Employee's name, identification number and signature
 - d. Date of training
 - e. Verification document or record confirming satisfaction of the training requirement
 - f. Documentation related to exceptions for training requirements and extensions of qualification.
4. Records shall be retained for the following types of training:
 - a. General Employee Radiological Training
 - b. Radiological Worker Training
 - c. Radiation Control Technologist Training
 - d. Periodic retraining
 - e. Orientation and training of visitors
 - f. Training of emergency response personnel performed by the RCG.
5. The following instructional materials shall be maintained:
 - a. Instructor's manuals, course content, or lesson plans containing topical outlines, revisions, and approval date.
 - b. Video and audio instructional materials, including the dates and lessons for which they were used.
 - c. Handouts or other materials retained with the master copy of the course.

726 Exposure Investigations

When gaps in the dosimetry records occur or it is necessary to make adjustments to recorded exposures, an exposure investigation shall be performed to estimate the missing exposure or to document the reasons for the adjustment. The exposure investigation form is placed into the person's individual monitoring record in order to maintain an accurate and complete radiation exposure history.



PART 3 Visitors

731 Record Requirements

For visitors the following records shall be maintained if applicable:

1. Documentation of completion of Visitor Orientation Training
2. Individual monitoring records-for monitoring conducted by Jefferson Lab.

732 Reports

Dose reports shall be provided to those visitors who request a report.



PART 4 Radiological Control Procedures

741 Policies, Procedures and Radiological Work Permits

Records of the Radiation Control Group consisting of policy statements, procedures, Radiological Work Permits and supporting data shall be maintained. The records should be maintained in a chronological sequence that will allow correlation with the corresponding support information. For example, procedures for performing radiation surveys should be identifiable with the survey results. Completed Radiological Work Permits shall be maintained.

742 ALARA Records

Records of As-Low-As-Reasonably-Achievable (ALARA) plans, goals, and modifications to procedures and changes to facilities, and training shall be maintained to demonstrate the adequacy of the ALARA efforts.

743 Quality Assurance Records

Records of internal audits, quality assurance records, and records of other reviews shall be maintained to document program content and implementation.

PART 5 Radiological Monitoring

751 General Requirements

The following information shall be documented and maintained:

- a. Results of monitoring for radiation and radioactive materials as required by Articles [413](#), [452](#), and [551-555](#).
- b. Results of surveys, measurements, and calculations used to determine individual occupation exposure from external and internal sources as required by Articles [511-555](#).
- c. Results of surveys for the release of material and equipment as required by Articles [421](#), [422](#), and [553](#).
- d. Results of maintenance and calibration performed on instruments and equipment as required by Articles [563](#), [564](#), and [565](#).
- e. Results of continuous computer logging of Controlled Area Radiation Monitors (CARMs), and other associated instrumentation used in monitoring radiological conditions.

752 Radiation Surveys

The JLab Radiological Control Program requires the performance of radiation and contamination surveys (as appropriate) to determine existing conditions in a given location. Maps with sufficient detail to permit identification of original survey and sampling locations shall be maintained. Records should contain sufficient detail to be meaningful even after the originator is no longer available. Radiological surveys shall be recorded on appropriate standard forms and should include the following common elements:

1. Date, time and purpose of the survey.
2. General and specific location of the survey.
3. Name and signature of the surveyor or analyst.
4. Pertinent information needed to interpret the survey results.
5. Reference to a specific Radiological Work Permit if the survey is performed to support the permit.
6. Instrument model and serial number.
7. Results of the measurements of area dose rates.

753 Contamination Surveys

In addition to the elements required by [Article 752](#), records of contamination surveys should include, at a minimum, the following information:

1. Contamination levels (using appropriate units) and appropriate supporting parameters including counting efficiency, counting time, correction factors, type of radiation and whether the contamination was fixed or removable.
2. Location of areas found to contain high concentrations of localized contamination.
3. Follow-up survey results for decontamination processes cross-referenced to the original survey.

754 Airborne Radioactivity

In addition to the elements provided in [Article 752](#), records of airborne radioactivity shall include, at a minimum, the following information:

1. Model and serial number of the sampler or location of fixed sampler.
2. Air concentrations in general areas.
3. Supporting parameters, including collection efficiency, flow rate, duration of sampling, correction factors and filter medium.



PART 6 Instrumentation and Calibration Records

761 Calibration and Operational Checks

1. Calibration records shall be maintained and include frequencies, method, dates, personnel, training and traceability of calibration sources to National Institute of Science and Technology or other acceptable standards. Calibration records shall be maintained for the following equipment:
 - a. Portable survey instruments
 - b. Fixed radiation measuring equipment
 - c. Process and effluent monitors and sampling equipment
 - d. Area Radiation monitors
 - e. Pocket and electronic dosimeters
 - f. Air sampling equipment
 - g. Tool and waste monitoring equipment
 - h. Laboratory radiation measuring equipment
2. Documentation of instrument operational checks should be maintained for a period not less than the calibration period of the instrument.
3. Maintenance histories, including the nature of any defects and corrective actions taken, and calibration results for each instrument shall be created and retained.

762 Special Calibration Records

Records of additional tests and checks of instrumentation used in conjunction with a suspected overexposure, questionable indication or unusual occurrence shall be retained. In addition, records of special instrument calibrations and modifications made in accordance with [Article 563.5](#) should be retained.

PART 7 Records Management

771 Media

A combination of media may be used for a comprehensive records system. For records that have long-term retention requirements and are stored on media subject to degradation or obsolescence, the records system shall provide for conversion to a more stable medium. All records shall be stored in a manner that ensures their integrity, retrievability and security.

Records required under RadCon Supplement [Chapter 7](#) should be duplicated with the duplicate maintained in a location remote from the original records.

All required records shall be transferred to the DOE upon cessation of activities at Jefferson Lab that cause radiation exposure to individuals.

772 Computerization of Records

1. Records may be transferred to electronic storage media provided certain precautions are taken to ensure that the information is maintained in a retrievable configuration.
2. Controls for the use and handling of electronic storage media should include the following:
 - a. A master index of documents on the electronic storage medium
 - b. A program to ensure back-up and retrievability of information
 - c. Quality control during data entry and analysis
 - d. Prevention of unauthorized manipulation of data
 - e. Assurance that previously stored information is retrievable and useable after system modifications.
3. Optical disks may be used to store records if the optical disks satisfy the following:
 - a. A reliable system to prevent overwriting or erasure of records
 - b. Software and user controls consistent with Article 772.2
 - c. Manufacturer recommendations relating to software control, disk life expectancy, environmental storage conditions and maintenance incorporated into policies and procedures
 - d. Quality controls on the imaging processes.

773 Physical Protection of Records

1. Methods for protecting documents shall include at a minimum fire rated cabinets and duplicate storage, or combinations of these.
2. Storage arrangements should address physical damage that could be caused by temperature extremes, moisture, infestation, electromagnetic fields, excessive light, stacking, theft and vandalism.
3. Records should, as a minimum, be protected from:
 - a. Exposure to fire, equivalent to an Underwriters Laboratories, Inc., 1.5-hour, or greater, fire resistance rating
 - b. Exposure to water damage caused by a 100-year flood
 - c. Exposure to windstorm velocities of 100-year recurrence.



PART 8 Radiological Reporting

781 Reports to Individuals

Radiation exposure data for individuals monitored in accordance with [Chapter 5](#), Parts [1](#) and [2](#), shall be reported as specified in this section. The information shall include the data required under Article 781. Each notification and report shall be in writing and include: the DOE site or facility name, the name of the individual, and the individual's social security number, employee number, or other unique identification number.

1. Upon the request from an individual terminating employment, records of exposure shall be provided to that individual as soon as the data are available, but not later than 90 days after termination. A written estimate of the radiation dose received by that employee based on available information shall be provided at the time of termination, if requested.
2. Detailed information concerning any individual's exposure shall be made available to the individual upon request of that individual, consistent with the provisions of the Privacy Act (5 U.S.C. 552a).

782 Annual Radiation Report

Jefferson Lab shall, on an annual basis, provide a radiation dose report to each individual monitored during the year at that site or facility in accordance with Articles [511](#), [512](#), [521](#).

1. When Jefferson Lab is required to report to the DOE, pursuant to Departmental requirements for occurrence reporting and processing, any exposure of an individual to radiation and/or radioactive material, or planned special exposure in accordance with [Article 213](#), Jefferson Lab shall also provide that individual with a report of his or her exposure data included therein. Such report shall be transmitted at a time not later than the transmittal to the Department.



PART 9 Distribution and Use of Controlled Documents

The Radiation Control Group (RCG) shall track forms or templates used in the creation of records. A title and form number shall be assigned by the RCG. A revision of the Radiological Control Supplement is not necessary for each form revision. The RCG is responsible for ensuring that current forms and applicable instructions for their use are distributed and used.

1. For the purposes of this Chapter, controlled documents are the following:
 - a. Radiation Protection Program Plan (RPP)
 - b. Radiological Control Manual
 - c. RCG Forms
 - d. RCG Procedures
2. The distribution of controlled documents shall be limited to Radiation Protection Group staff, JRRP members, senior staff and those whose job requires their use. Each copy shall be assigned a number. The user of the controlled document shall be issued revisions and instructions for making each revision by a memo from the RCG. A return memo with the signature of the controlled document holder shall certify that the revision has been received and installed in the document.
3. Controlled documents in the work place should be easily accessible to those who need them. Photocopying sections for inclusion in TOSPs and OSPs or RCOPs is allowed. Photocopying the controlled document for the purpose of field use is permitted but copies shall be conspicuously marked. Paper copies shall be maintained by the RCG for loan and copies should be available electronically as technology permits (e.g., the docushare system).



Table of Acronyms

ALARA	As Low As Reasonably Achievable	PSS	Personal Safety System
ALI	Annual Limit on Intake	R/hr	Roentgen per hour
ARM	Assigned Radiation Monitor	RCA	Radiologically Controlled Area
CARM	Controlled Area Radiation Monitor	RCG	Radiological Control Group
Ci	Curie	RCM	Radiation Control Manager
EH&S	Environmental Health and Safety	RCOP	Radiological Controls Operating Procedure
DAC	Derived Air Concentration	RCT	Radiological Control Technologist
GERT	General Employee Radiation Training	rem	Roentgen equivalent man
H-3	Tritium	RSDR	Radiation Safety Deviation Report
He-3	Helium 3	RW I	Radiological Worker I
HRA	High Radiation Area	RW II	Radiological Worker II
HRSD	Hampton Roads Sanitation District	RWP	Radiological Work Permit
JRRP	Jefferson Lab Radiation Review Panel	SER	Site Environmental Report
NER	Notable Event Report	SI	Standard International
NESHAP	National Emission Standards for Hazardous Air Pollutants	SOP	Standard Operating Procedure
OSP	Operational Safety Procedure	TOSP	Temporary Operational Safety Procedure
PAAA	Price Anderson Amendments Act	VPDES	Virginia Pollutant Discharge Elimination System



Glossary

Jefferson Lab Radiation Control Manual

GLOSSARY

Abnormal Situation Unplanned event or condition that adversely affects, potentially affects, or indicates degradation in the safety, security, environmental or health protection performance or operation of a facility.

Absorbed dose (D) The energy absorbed by matter from ionizing radiation per unit mass of irradiated material at the place of interest in that material. The absorbed dose is expressed in units of rad (or gray) (1 rad = 0.01 gray).

Accountable sealed radioactive source A sealed radioactive source having a half-life equal to or greater than 30 days and an isotopic activity equal to or greater than the corresponding value provided in appendix E of this part.

Activation Process of producing a radioactive material by bombardment with neutrons, protons or other nuclear particles.

Administrative control level A numerical dose constraint established at a level below the regulatory limits to administratively control and helps reduce individual and collective dose.

Airborne radioactive material or airborne radioactivity Radioactive material dispersed in the air in the form of dusts, fumes, particulates, mists, vapors, or gases.

Airborne radioactivity area Any area, accessible to individuals, where:

- (1) The concentration of airborne radioactivity, above natural background, exceeds or is likely to exceed the derived air concentration (DAC) values listed in appendix A or appendix C of this part; or
- (2) An individual present in the area without respiratory protection could receive an intake exceeding 12 DAC-hours in a week.

ALARA "As Low As is Reasonably Achievable," which is the approach to radiation protection to manage and control exposures (both individual and collective) to the work force and to the general public to as low as is reasonable, taking into account social, technical, economic, practical, and public policy considerations. As used in this part, ALARA is not a dose limit but a process which has the objective of attaining doses as far below the applicable limits of this part as is reasonably achievable.



ALARA Committee Multidiscipline forum that reviews and advises management on improving progress toward minimizing radiation exposure and radiological releases.

Ambient Air The general air in the area of interest (e.g., the general room atmosphere), as distinct from a specific stream or volume of air that may have different properties.

Annual limit on intake (ALI) The derived limit for the amount of radioactive material taken into the body of an adult worker by inhalation or ingestion in a year. ALI is the smaller value of intake of a given radionuclide in a year by the reference man (ICRP Publication 23) that would result in a committed effective dose equivalent of 5 rems (0.05 sievert) or a committed dose equivalent of 50 rems (0.50 sievert) to any individual organ or tissue.

Assessment Evaluation or appraisal of a process, program or activity to estimate its acceptability.

Background Radiation from:

- (i). Naturally occurring radioactive materials which have not been technologically enhanced;
- (ii). Cosmic sources;
- (iii). Global fallout as it exists in the environment (such as from the testing of nuclear explosive devices);
- (iv). Radon and its progeny in concentrations or levels existing in buildings or the environment which have not been elevated as a result of current or prior activities; and
- (v). Consumer products containing nominal amounts of radioactive material or producing nominal amounts of radiation.

Becquerel (bq) The International System (SI) unit for activity of radioactive material. One becquerel is that quantity of radioactive material in which one atom is transformed per second or undergoes one disintegration per second.

Bioassay The determination of the kinds, quantities, or concentrations, and, in some cases, locations of radioactive material in the human body, whether by direct measurement or by analysis and evaluation of radioactive materials excreted or removed from the human body.

Calibration To adjust and/or determine either:

- (i). The response or reading of an instrument relative to a standard (e.g., primary, secondary, or tertiary) or to a series of conventionally true values; or
- (ii). The strength of a radiation source relative to a standard (e.g., primary, secondary, or tertiary) or conventionally true value.

Collective dose The sum of the total effective dose equivalent values for all individuals in a specified population. Collective dose is expressed in units of person-rem (or person-sievert).

Committed dose equivalent ($H_{T,50}$) The dose equivalent calculated to be received by a tissue or organ over a 50-year period after the intake of a radionuclide into the body. It does not include contributions from radiation sources external to the body. Committed dose equivalent is expressed in units of rem (or sievert) (1 rem = 0.01 sievert).



Committed effective dose equivalent ($H_{E,50}$) The sum of the committed dose equivalents to various tissues in the body ($H_{T,50}$), each multiplied by the appropriate weighting factor (w_T)-that is, $H_{E,50}=w_T H_{T,50}$. Committed effective dose equivalent is expressed in units of rem (or sievert).

Company-issued clothing Clothing provided by the company, such as work coveralls and shoes. For radiological control purposes, company-issued clothing shall be considered the same as personal clothing.

Containment device Barrier such as a glovebag, glovebox or tent for inhibiting the release of radioactive material from a specific location.

Contamination area Any area, accessible to individuals, where removable surface contamination levels exceed or are likely to exceed the removable surface contamination values specified in appendix D of this part, but do not exceed 100 times those values.

Contamination reduction corridor A defined pathway through a hazardous waste site contamination reduction zone where decontamination occurs.

Contamination survey Use of swipes or direct instrument surveys to identify and quantify radioactive material on personnel, on equipment or in areas.

Continuing training Training scheduled over a specified time such as over a two-year period for the purpose of maintaining and improving technical knowledge and skills.

Continuous air monitor (CAM) An instrument that continuously samples and measures the levels of airborne radioactive materials on a "real-time" basis and has alarm capabilities at preset levels.

Contractor Any entity under contract with the Department of Energy with the responsibility to perform activities at a DOE site or facility.

Contractor senior site executive The person at a DOE contractor-operated facility or site who has final on-site corporate authority and is often called President, General Manager, Site Manager or Director.

Controlled area Any area to which access is managed by or for DOE to protect individuals from exposure to radiation and/or radioactive material.

Conventionally true value of a quantity The commonly accepted, best estimate of the true value of a quantity. The conventionally true value and the associated uncertainty will normally be determined by comparison with a national or transfer standard, using a reference instrument that has been calibrated against a national or transfer standard.

Counseling Advice, information exchange and guidance provided to employees on radiologically related topics, such as dose perspectives; potential health effects from radiation exposure; skin contaminations; contaminated wounds; internally deposited radioactivity; pregnancy; and radiation exposure. This advice and guidance is normally provided by knowledgeable, senior professionals from the Radiological Control Organization and other organizations, such as Medical, as appropriate.



Critical mass The smallest mass of fissionable material that will support a self-sustaining chain reaction under specified conditions.

Critique Meetings of personnel involved in or knowledgeable about an event (either a success or an abnormal event) to document a chronological listing of the facts.

Cumulative total effective dose equivalent The sum of all total effective dose equivalent values recorded for an individual, where available, for each year occupational dose was received, beginning January 1, 1989.

Declared pregnant worker A woman who has voluntarily declared to her employer, in writing, her pregnancy for the purpose of being subject to the occupational exposure limits to the embryo/fetus as provided in §835.206. This declaration may be revoked, in writing, at any time by the declared pregnant worker.

Decontamination Process of removing radioactive contamination and materials from personnel, equipment or areas.

Deep dose equivalent The dose equivalent derived from external radiation at a depth of 1 cm in tissue.

Derived air concentration (DAC) For the radionuclides listed in appendix A of this part, the airborne concentration that equals the ALI divided by the volume of air breathed by an average worker for a working year of 2000 hours (assuming a breathing volume of 2400 m³). For the radionuclides listed in appendix C of this part, the air immersion DACs were calculated for a continuous, non-shielded exposure via immersion in a semi-infinite atmospheric cloud.

Derived air concentration-hour (DAC-hour) The product of the concentration of radioactive material in air (expressed as a fraction or multiple of the DAC for each radionuclide) and the time of exposure to that radionuclide, in hours.

Disintegration per minute (dpm) The rate of emission by radioactive material as determined by correcting the counts per minute observed by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.

DOE activity An activity taken for or by DOE in a DOE operation or facility that has the potential to result in the occupational exposure of an individual to radiation or radioactive material. The activity may be, but is not limited to, design, construction, operation, or decommissioning. To the extent appropriate, the activity may involve a single DOE facility or operation or a combination of facilities and operations, possibly including an entire site or multiple DOE sites.

DOELAP Department of Energy Laboratory Accreditation Program for personnel dosimetry.

Dose A general term for absorbed dose, dose equivalent, effective dose equivalent, committed dose equivalent, committed effective dose equivalent, or total effective dose equivalent as defined in this part.



Dose assessment Process of determining radiological dose and uncertainty included in the dose estimate, through the use of exposure scenarios, bioassay results, monitoring data, source term information and pathway analysis.

Dose equivalent (H) The product of absorbed dose (D) in rad (or gray) in tissue, a quality factor (Q), and other modifying factors (N). Dose equivalent is expressed in units of rem (or sievert) (1 rem = 0.01 sievert).

Effective dose equivalent (HE) The summation of the products of the dose equivalent received by specified tissues of the body (H_T) and the appropriate weighting factor (w_T)--that is, $HE = \sum w_T H_T$. It includes the dose from radiation sources internal and/or external to the body. For purposes of compliance with this part, deep dose equivalent to the whole body may be used as effective dose equivalent for external exposures. The effective dose equivalent is expressed in units of rem (or sievert).

Embryo/fetus Developing human organism from conception until birth. Same as unborn child.

Engineering controls Use of components and systems to reduce airborne radioactivity and the spread of contamination by using piping, containments, ventilation, filtration or shielding.

Entrance or access point Any location through which an individual could gain access to areas controlled for the purposes of radiation protection. This includes entry or exit portals of sufficient size to permit human entry, irrespective of their intended use.

External dose or exposure That portion of the dose equivalent received from radiation sources outside the body (e.g., "external sources").

Extremity Hands and arms below the elbow or feet and legs below the knee.

Facility For the purpose of this Manual, a facility includes systems, buildings, utilities, and related activities whose use is directed to a common purpose at a single location. Example include: accelerators, storage areas, test loops, nuclear reactors, radioactive waste disposal systems and burial grounds, testing laboratories, research laboratories, and accommodations for analytical examinations of components. Also includes: pipelines, ponds, impoundments, landfills and the like, and motor vehicles, rolling stock, and aircraft.

Filter integrity test Test performed on High-Efficiency Particulate Air (HEPA) filters to identify any damage to the filter or leakage around the filter.

Fixed contamination Radioactive material that cannot be readily removed from surfaces by nondestructive means, such as casual contact, wiping, brushing or laundering.

Flash X-ray unit Any device that is capable of generating pulsed X-rays.

Frisk or frisking Process of monitoring personnel for contamination. Frisking can be performed with hand-held survey instruments, automated monitoring devices or by a Radiological Control Technician.



General employee An individual who is either a DOE or DOE contractor employee; an employee of a subcontractor to a DOE contractor; or an individual who performs work for or in conjunction with DOE or utilizes DOE facilities.

Gestation period The time from conception to birth, approximately 9 months.

Gray (Gy) SI unit of absorbed dose. One gray is equal to an absorbed dose of 1 joule per kilogram (100 rads).

High contamination area Any area, accessible to individuals, where removable surface contamination levels exceed or are likely to exceed 100 times the removable surface contamination values specified in appendix D of this part.

High radiation area Any area, accessible to individuals, in which radiation levels could result in an individual receiving a deep dose equivalent in excess of 0.1 rem (0.001 sievert) in 1 hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates.

High-efficiency particulate air (HEPA) filter Throwaway extended pleated medium dry-type filter with 1) a rigid casing enclosing the full depth of the pleats, 2) a minimum particle removal efficiency of 99.97 percent for thermally generated monodisperse di-octyl phthalate smoke particles with a diameter of 0.3 micrometer, and 3) a maximum pressure drop of 1.0 inch w.g. when clean and operated at its rated airflow capacity.

Hot particle Fuel, activated corrosion products, other particles of small size that have a high specific activity as a result of nuclear fission neutron activation or activation by exposure to particles or radiation from an accelerator.

Hot spot Localized source of radiation or radioactive material normally within facility piping or equipment. The radiation levels of hot spots exceed the general area radiation level by more than a factor of 5 and are greater than 100 mrem (1 mSv) per hour on contact.

Individual Any human being.

Infrequent or first-time activities Radiological work activities or operations that require special Management attention and consideration of new or novel radiological controls. The designation of infrequent or first-time activities is specifically applicable to facilities that conduct routine and recurring process operations, and is not applicable to facilities that routinely conduct first-time activities, such as experimental or research facilities.

Internal dose or exposure That portion of the dose equivalent received from radioactive material taken into the body (e.g., "internal sources").

Irradiator Sealed radioactive material used to irradiate other materials that have the potential to create a radiation level exceeding 500 rad (5 grays) in 1 hour at 1 meter. Although not addressed in this Manual, acceptable radiological controls for irradiator use are specified in Title 10, Code of Federal Regulations, Part 20.1603.

Lens of the eye dose equivalent The external exposure of the lens of the eye and is taken as the dose equivalent at a tissue depth of 0.3 cm.



Lifetime dose Total occupational exposure over a worker's lifetime, including external and committed internal dose.

Low-level waste Waste that contains radioactivity and is not classified as high-level waste, transuranic waste, spent nuclear fuel or byproduct material as defined in Section 11e(2) of the Atomic Energy Act, as amended. Test specimens of fissionable material irradiated only for research and development and not for production of power or plutonium may be classified as low-level waste provided the concentration of transuranic activity is less than 100 nCi/g.

Member of the public An individual who is not a general employee. An individual is not a "member of the public" during any period in which the individual receives an occupational dose.

Minor An individual less than 18 years of age.

Mixed waste Waste containing both radioactive and hazardous components as defined by the Atomic Energy Act and the Resource Conservation and Recovery Act, respectively.

Monitoring The measurement of radiation levels, airborne radioactivity concentrations, radioactive contamination levels, quantities of radioactive material, or individual doses and the use of the results of these measurements to evaluate radiological hazards or potential and actual doses resulting from exposures to ionizing radiation.

Nonstochastic effects Effects due to radiation exposure for which the severity varies with the dose and for which a threshold normally exists (e.g., radiation-induced opacities within the lens of the eye).

Nuclear criticality A self-sustaining chain reaction, i.e., the state in which the effective neutron multiplication constant of system of fissionable material equals or exceeds unity.

Occupational dose An individual's dose due to exposure to ionizing radiation (external and internal) as a result of that individual's work assignment. Occupational dose does not include planned special exposures, exposure received as a medical patient, background radiation, or voluntary participation in medical research programs.

Person Any individual, corporation, partnership, firm, association, trust, estate, public or private institution, group, Government agency, any State or political subdivision of, or any political entity within a State, any foreign government or nation or other entity, and any legal successor, representative, agent or agency of the foregoing; provided that person does not include the Department or the United States Nuclear Regulatory Commission.

Personal protective equipment Equipment such as respirators, face shields and safety glasses used to protect workers from excessive exposure to radioactive or hazardous materials.

Personnel dosimetry Devices designed to be worn by a single person for the assessment of dose equivalent such as film badges, thermo luminescent dosimeters (TLDs), and pocket ionization chambers.



Personnel monitoring Systematic and periodic estimate of radiation dose received by personnel during working hours. Also, the monitoring of personnel, their excretions, skin or any part of their clothing to determine the amount of radioactivity present.

Planned special exposure Preplanned, infrequent exposure to radiation, separate from and in addition to the annual dose limits.

Prefilter Filter that provides first stage air filtration to remove larger particulates and prolong the efficient use of a HEPA filter.

Prenatal radiation exposure The exposure of an embryo/fetus to radiation.

Primary dosimeter A dosimeter worn on the body used to obtain the formal record of whole body radiation dose.

Protective clothing Clothing provided to personnel to minimize the potential for skin, personal and company issued clothing contamination. Also referred to as "anticontamination clothing," "anti-Cs" and "PCs."

Public Any individual or group of individuals who is not occupationally exposed to radiation or radioactive material. An individual is not a "member of the public" during any period in which the individual receives an occupational dose.

Qualification standard The explicit performance requirements for minimum proficiency in technical, academic, and site- specific knowledge and practical skills used in determining satisfactory completion of training programs. The qualification standard is used to qualify radiological control technicians (RCTs) at DOE facilities.

Quality factor The modifying factor used to calculate the dose equivalent from the absorbed dose; the absorbed dose (expressed in rad or gray) is multiplied by the appropriate quality factor. When spectral data are insufficient to identify the energy of the neutrons, a quality factor of 10 shall be used.

Rad Unit of absorbed dose. One rad is equal to an absorbed dose of 100 ergs per gram or 0.01 joules per kilogram (0.01 gray).

Radiation ionizing radiation means alpha particles, beta particles, gamma rays, X- rays, neutrons, high- speed electrons, high-speed protons, and other particles capable of producing ions. Radiation as used in this part, does not include non-ionizing radiation, such as radio- or micro-waves, or visible, infrared, or ultraviolet light.

Radiation area Any area accessible to individuals in which radiation levels could result in an individual receiving a deep dose equivalent in excess of 0.005 rem (0.05millisievert) in 1 hour at 30 centimeters from the source or from any surface that the radiation penetrates.

Radiation survey Measurement with instrumentation to evaluate and assess the presence of radioactive materials or other sources of radiation under a specific set of conditions.



Radioactive material For the purposes of this Manual, radioactive material includes any material, equipment or system component determined to be contaminated or suspected of being contaminated. Radioactive material also includes activated material, sealed and unsealed sources, and material that emits radiation.

Radioactive material area Any area within a controlled area, accessible to individuals, in which items or containers of radioactive material exist and the total activity of radioactive material exceeds the applicable values provided in Appendix 2F of this part.

Radioactive material transportation The movement of radioactive material by aircraft, rail, vessel, or highway vehicle when such movement is subject to Department of Transportation regulations or DOE Orders that governs such movements. Radioactive material transportation does not include preparation of material or packaging for transportation, monitoring required by this part, storage of material awaiting transportation, or application of markings and labels required for transportation.

Radioactive waste Solid, liquid or gaseous material that contains radionuclides regulated under the Atomic Energy Act, as amended, and is of negligible economic value considering the cost of recovery.

Radioactivity A natural and spontaneous process by which the unstable atoms of an element emit or radiate excess energy from their nuclei and, thus, change (or decay) to atoms of a different element or to a lower energy state of the same element.

Radiography Examination of the structure of materials by nondestructive methods, using a radioactive source or a radiation generating device.

Radiological area Any area within a controlled area defined in this section as a "radiation area," "high radiation area," "very high radiation area," "contamination area," "high contamination area," or "airborne radioactivity area."

Radiological buffer area (RBA) An intermediate area established to prevent the spread of radioactive contamination and to protect personnel from radiation exposure.

Radiological control hold point Cautionary step in a technical work document requiring the radiological control organization to perform some action or verification. The radiological control hold point requirements should be satisfactorily completed before the work is continued.

Radiological posting Sign, marking, or label that indicates the presence or potential presence of radiation or radioactive materials.

Radiological work Any work that requires the handling of radioactive material or which requires access to Radiation Areas, High Radiation Areas, Contamination Areas, High Contamination Areas or Airborne Radioactivity Areas.



Radiological work permit (RWP) Permit that identifies radiological conditions, establishes worker protection and monitoring requirements, and contains specific approvals for radiological work activities. The Radiological Work Permit serves as an administrative process for planning and controlling radiological work and informing the worker of the radiological conditions.

Radiological worker A general employee whose job assignment involves operation of radiation producing devices or working with radioactive materials, or who is likely to be routinely occupationally exposed above 0.1 rem (0.001 sievert) per year total effective dose equivalent.

Real-time air monitoring Measurement of the concentrations or quantities of airborne radioactive materials on a continuous basis.

Refresher training Training scheduled on the alternate year when full retraining is not completed for Radiological Worker I and Radiological Worker 11 personnel.

Release to uncontrolled areas Release of material from administrative control after confirming that the residual radioactive material meets the guidelines in DOE 5400.5.

REM Unit of dose equivalent. Dose equivalent in rem is numerically equal to the absorbed dose in rad multiplied by a quality factor, distribution factor and any other necessary modifying factor (1 rem = 0.01 sievert).

Removable contamination Radioactive material that can be removed from surfaces by nondestructive means, such as casual contact, wiping, brushing or washing.

Representative sample A sample that closely approximates both the concentration of activity and the physical and chemical properties of material (e.g., particle size and solubility in case of air sampling of the aerosol to which workers may be exposed).

Respiratory protective device An apparatus, such as a respirator, worn by an individual for the purpose of reducing the individual's intake of airborne radioactive materials.

Respiratory protective equipment Equipment used to protect personnel from inhalation of radioactive or hazardous materials.

Sealed radioactive source A radioactive source manufactured, obtained, or retained for the purpose of utilizing the emitted radiation. The sealed radioactive source consists of a known or estimated quantity of radioactive material contained within a sealed capsule, sealed between layer(s) of nonradioactive material, or firmly fixed to a non-radioactive surface by electroplating or other means intended to prevent leakage or escape of the radioactive material. Sealed radioactive sources do not include reactor fuel elements, nuclear explosive devices, and radioisotope thermoelectric generators.

Shallow dose equivalent The dose equivalent deriving from external radiation at a depth of 0.007 cm in tissue.

Sievert (Sv) SI unit of any of the quantities expressed as dose equivalent. The dose equivalent in sieverts is equal to the absorbed dose in grays multiplied by the quality factor (1 Sv = 100 rems).



Site An area managed by DOE where access can be limited for any reason. The site boundary encompasses Controlled Areas.

Source leak test A test to determine if a sealed radioactive source is leaking radioactive material.

Source, sealed Radioactive material that is contained in a sealed capsule, sealed between layers of nonradioactive material or firmly fixed to a nonradioactive surface by electroplating or other means. The confining barrier prevents dispersion of the radioactive material under normal and most accidental conditions related to use of the source.

Standard radiation symbols Symbols designed and proportioned as illustrated in accordance with ANSI N2.1 for radiation symbols and ANSI N12.1 for fissile material.

Step-off pad Transition area between contaminated and non-contaminated areas that is used to allow exit of personnel and removal of equipment.

Sticky pad Step-off pad provided with a tacky surface to reduce the potential for inadvertently tracking contamination out of a contaminated area.

Stochastic effects Malignant and hereditary diseases for which the probability of an effect occurring, rather than its severity, is regarded as a function of dose without a threshold for radiation protection purposes.

Survey An evaluation of the radiological conditions and potential hazards incident to the production, use, transfer, release, disposal, or presence of radioactive material or other sources of radiation. When appropriate, such an evaluation includes a physical survey of the location of radioactive material and measurements or calculations of levels of radiation, or concentrations or quantities of radioactive material present.

Technical work document A term used to generically identify formally approved documents that direct work, such as procedures, work packages, or job or research plans.

Thermoluminescent dosimeter (TLD) Radiation monitoring device used to record the radiological exposure of personnel or areas to certain types of radiation.

Total effective dose equivalent (TEDE) The sum of the effective dose equivalent (for external exposures) and the committed effective dose equivalent (for internal exposures).

Very high radiation area Any area, accessible to individuals, in which radiation levels could result in an individual receiving an absorbed dose in excess of 500 rads (5 grays) in one hour at 1 meter from a radiation source or from any surface that the radiation penetrates.

Visitor Person requesting access to Controlled Areas who has not been trained to the level required to permit unescorted access.

Week A period of seven consecutive days.



Weighting factor (WT) Weighting factor (W_T) means the fraction of the overall health risk, resulting from uniform, whole body irradiation, attributable to specific tissue (T). The dose equivalent to tissue, (H_T), is multiplied by the appropriate weighting factor to obtain the effective dose equivalent contribution from that tissue.

Whole body For the purposes of external exposure, head, trunk (including male gonads), arms above and including the elbow, or legs above and including the knee.

Whole body dose The sum of the annual deep dose equivalent for external exposures and the committed effective dose equivalent for internal exposures.

Year The period of time beginning on or near January 1 and ending on or near December 31 of that same year used to determine compliance with the provisions of this part. The starting and ending date of the year used to determine compliance may be changed provided that the change is made at the beginning of the year and that no day is omitted or duplicated in consecutive years.